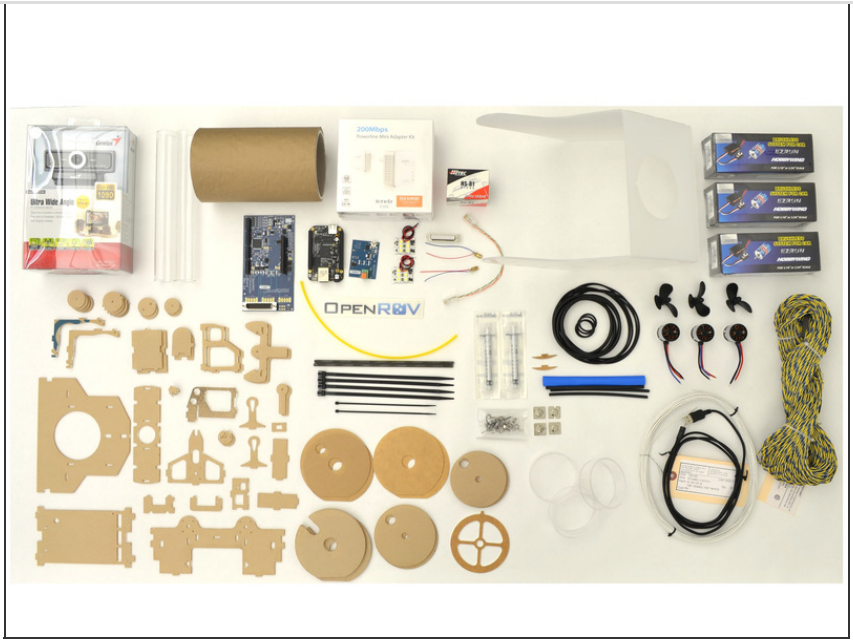
OpenROV

How to Assemble OpenROV 2.6

Written By: Eric Stackpole

Step 1 — How to Assemble OpenROV 2.6



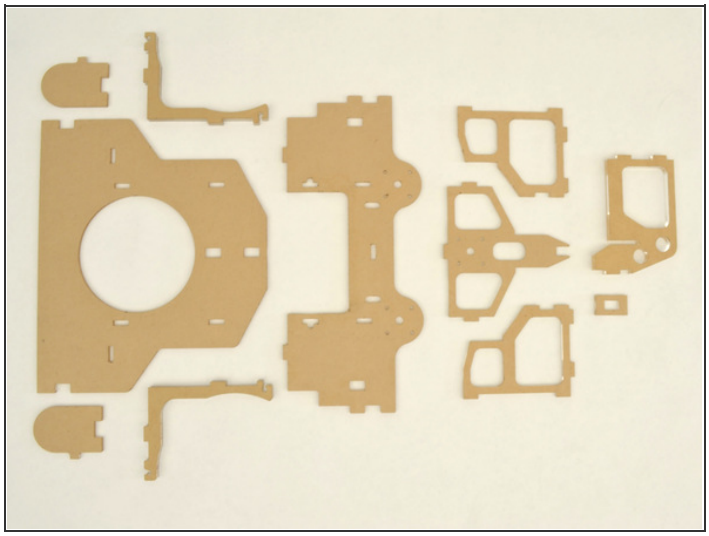
- This instruction set, for OpenROV v2.6, is a work in progress. We have posted the photos taken so far to help people with kits get a general idea of how things go together. Please post questions about the build on the OpenROV Forums.
- To build the ROV, you'll need the parts shown (which are all included in the v2.6 kit). If you're starting from scratch, you'll want to consult our Bill of Materials and Wiki page before getting started.
- **Tools you will need (not included in kit):**
- Glues/solvents/lubricants: Devcon "Flow Mix" 2-Ton Epoxy (two 14mL syringes should do it), Acrylic Cement and Hypo Applicator(BD-25), super glue, hot glue gun and sticks, silicone spray or jelly for lubricating o-rings and protecting motors
- Electronics/wiring tools: Soldering iron, solder, helping hands, safety glasses (recommended), wire strippers, flush cutters, heat gun, electrical tape, and a digital mulitmeter

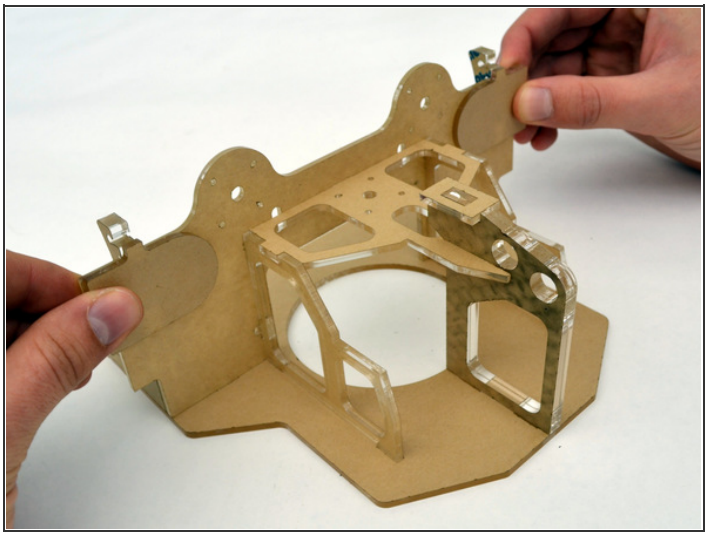
- Hand tools: Sandpaper, small hacksaw or pipesaw, small set of screwdrivers, tape measure with metric markings, needlenose pliers, and painter's or masking tape
- **Educators**: Use the Team Build Flowchart to manage multiple students working on a single OpenROV.

Step 2

- **Batteries & charger are not included in the kit**
- OpenROV 2.6 is designed so that many different "c-cell" sized rechargeable batters can be used.
- Please see the blog post HERE for information about batteries.
- If you plan on using the Trustfire Li-Ion 26650 batteries, no further action is needed.
- If you plan on using the Batteryspace Li-FePO4 batteries, which we recommend, you will need to build the adapter. The assembly instructions for this are HERE. Don't worry, we will remind you about this later in this guide after your battery tubes are assembled.
- Batteries, chargers, and adapters can be found in our webstore.

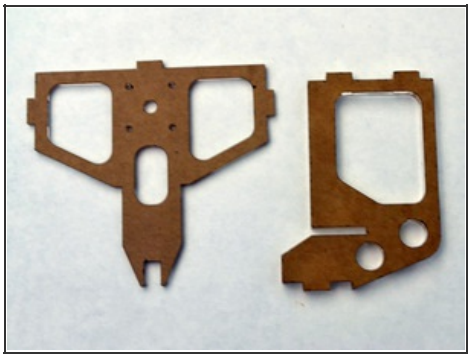
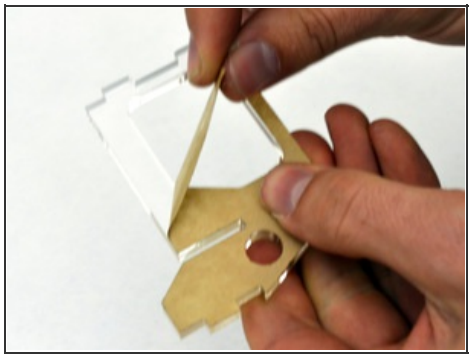
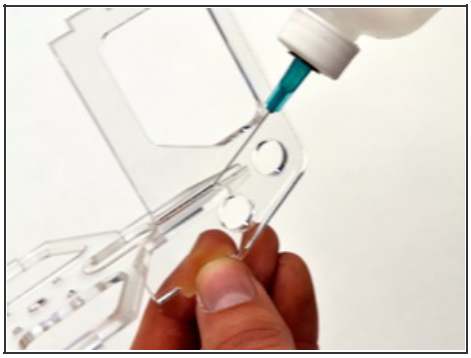
Step 3





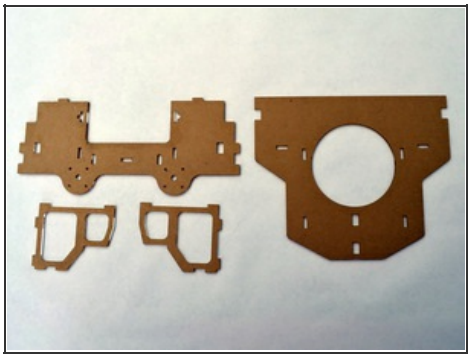
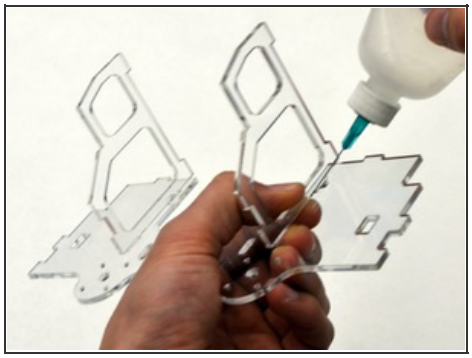
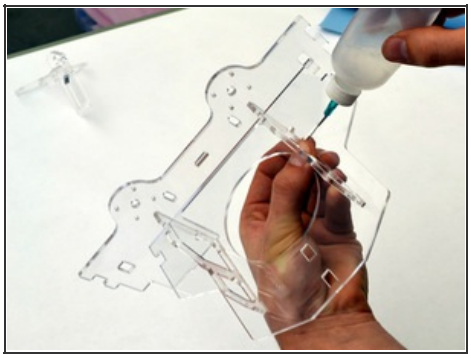
- To start out, put the internal structure together. You will need the pieces shown (which can be found in the large plastic bag in the kit). The internal structure acts as a central mounting frame for the motors, wiring harness, and electronics tube.
- The pieces for the internal structure come with a paper backing on them which can be removed. Before doing so, however, it is good to test fit all the pieces to get a feel for how they all go together.
- **Before you start, watch this great video on how to use acrylic cement from TAP Plastics.**

Step 4

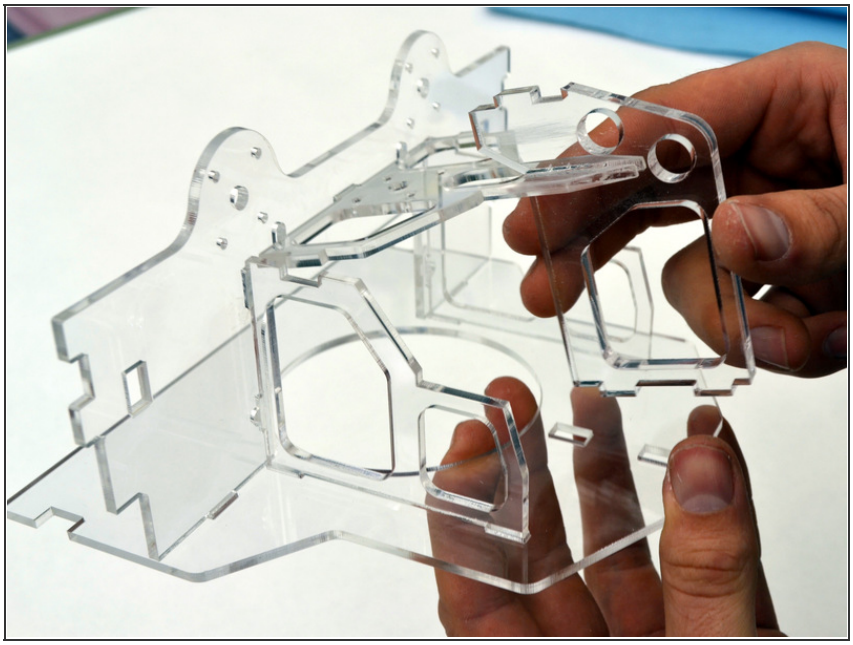
- Your very first step will be to cement together the ROV handle and horizontal shroud support... Here we go!!
- Remove the paper backing from both sides of the pieces and slide them together as shown.
- Make sure you push the pieces all the way together (this may take a little force).
- Use the edge between the two pieces to guide the tip of the syringe needle as you apply cement.
- The best way to apply cement is to hold the syringe bottle upright (tip at the top) and squeeze out a bunch of air, so when you turn the syringe bottle upside-down (and don't squeeze the bottle), air will burble inward and not allow cement to flow out. When you're ready to apply cement, lightly squeeze the bottle to overcome the vacuum pressure.
- The cement dries relatively fast so make sure everything is aligned before gluing.
- Now set aside, but not too far away as you will need this again soon!

Step 5

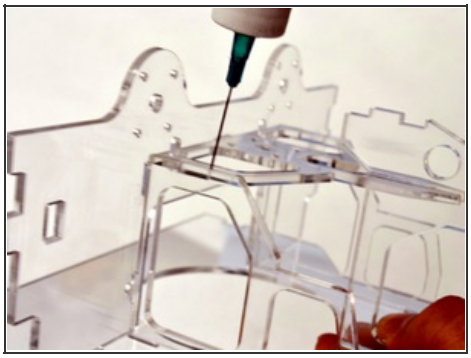
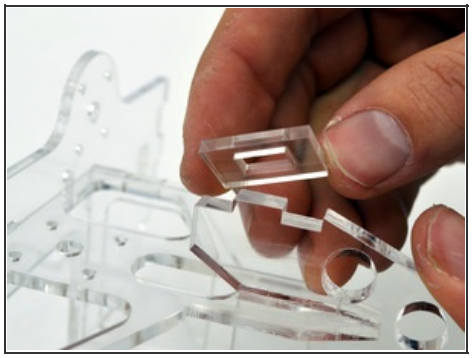
- Now it is time to cement the mounts for the motors.
- Remove the paper backing from both sides of all the pieces and assemble them together as shown. We will be cementing the three small pieces first.
- Once the pieces are in place apply the cement to bond them together.
- Ensure the pieces form 90 degree angles to the piece upon which they are being glued.
- Next attach the largest piece and cement it to the three that you just put together.

Step 6



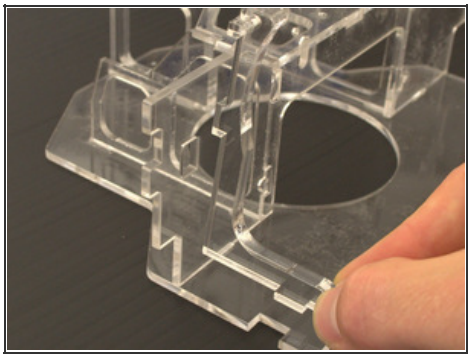
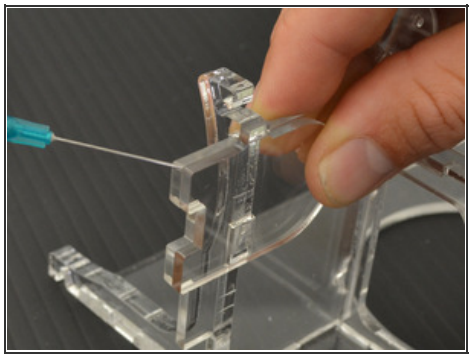
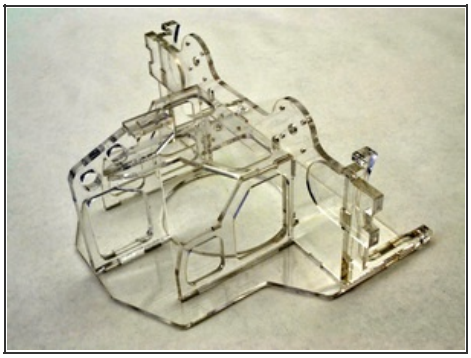
- Next, attach the handle/horizontal shroud support piece that you made in the previous step.
- It should be a snug fit, so don't hesitate to push a bit to get it in place.

Step 7

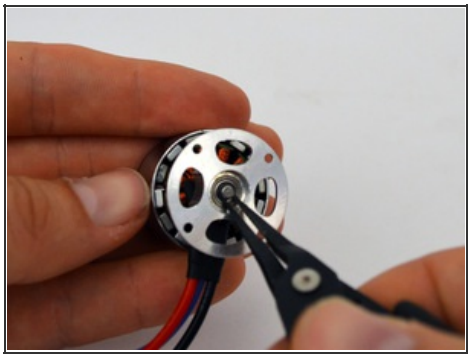
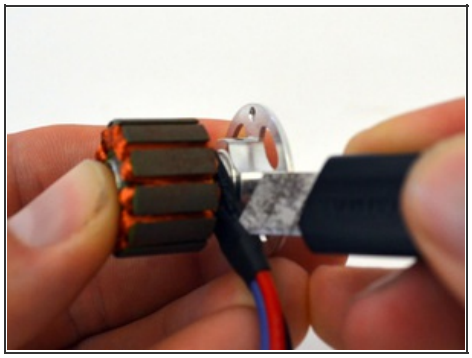
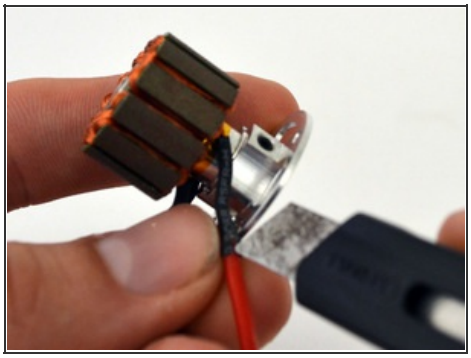
- Cement the handle to the motor mounting as seen in the first image.
- Next we will cement a little tab (the small rectangular piece with a hole in the center) to the top of the handle. Make sure to remove the paper before cementing it. This is for the propeller shrouds to rest against later.

Step 8

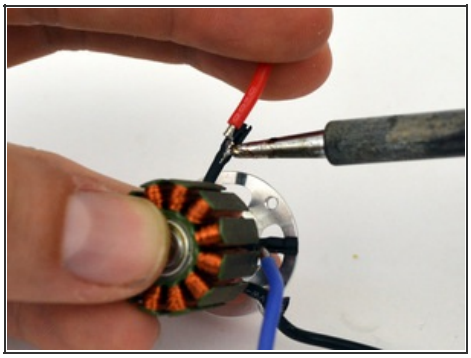
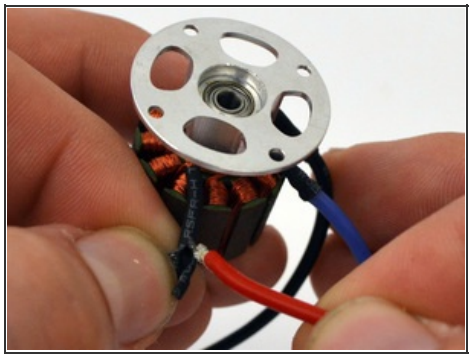
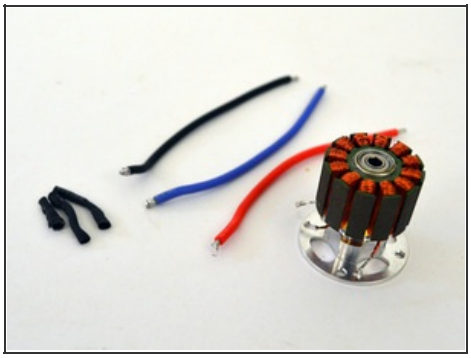
- You're almost done with the internal structure! After cementing the Main Tube Cradle pieces and Bulkhead Supports, you'll be done with the internal structure.
- We will attach the Main Tube Cradle pieces. These are the L shaped ones that hold the electronics tube. Once they are in place cement them together.
- Finally, we will attach the last two pieces! These "doublers" help to hold this assembly in the frame. The second image shows the pieces (the ones shaped like the monsters from pac-man) being cemented on.
- Because there are no notches or grooves to hold the doublers in place, you'll need to be careful that they are held in the correct position as the cement sets up.
- The Internal Structure is now assembled! Now is the time to inspect all the joints between each part and make sure every interface has been cemented. Apply additional cement to any gaps or missed joints.
- Congratulations! You have completed the internal frame assembly!

Step 9

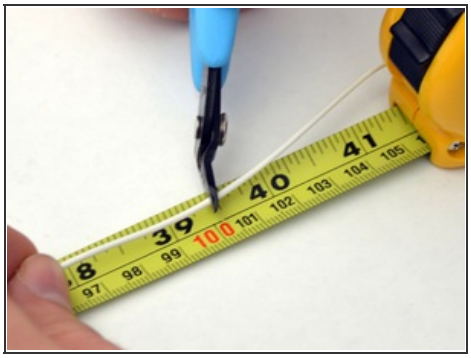
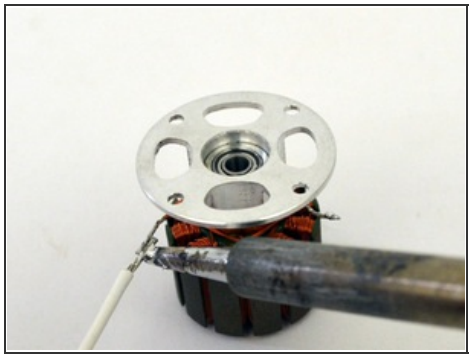
- We'll need to make a few modifications to the brushless motors so that they can work underwater. The main modification we'll make will be to attach new wire leads with waterproof insulation.
- Start by removing the motor bell (the metal cylinder surrounding the motor) using small pliers or a screw driver to pry off the c-clip. Once removed, the c-clip can be discarded.
- It is recommended that you wear eye protection while removing the c-clip as it has a tendency to fly off at a high velocity.
- Once the C-clip is removed, the bell can be pulled straight off the motor. It may take a fair amount of force before the bell comes off.
- Use a sharp razor to remove the outer shrink tubing from the motor lead bundle. Be sure not to damage the thin magnet wires coming from the motors, as this will damage the motor.
- Now cut a slit in the inner shrink tubing on each of the wires. The slit only needs to go from the center of the tubing outward (you don't need to cut along the entire length of the tubing) This way, you won't damage the wires coming from the motor, and you'll be able to pull off the shrink tubing once you de-solder the original motor leads.

Step 10

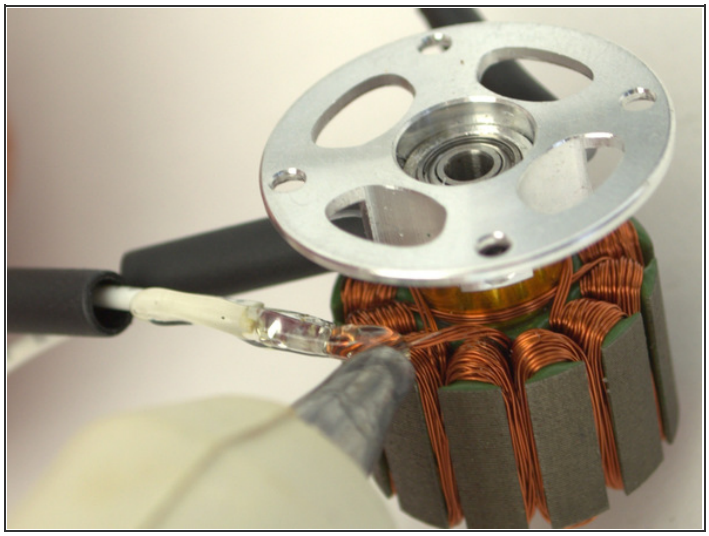
- Heat the solder junctions with an iron to remove the leadwires. After the leadwires have been pulled off, the shrink tubing should be easy to pull off as well.
- Small needle nose pliers are helpful for removing the heat shrink.

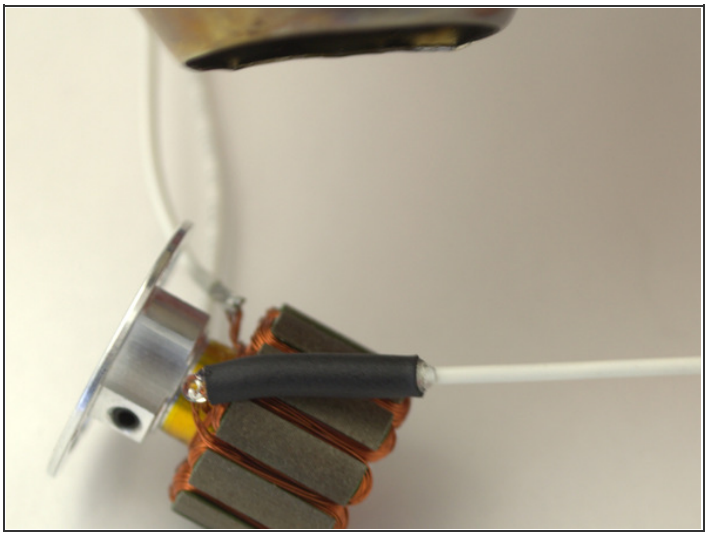
Step 11

- Next, cut a total of 17 pieces of one-meter long 20awg stranded wire. (Nine will be attached to the three motors, two will be attached to the spring terminals for the two battery packs, and six will be used as auxiliary wires for external devices.)
- Strip a small amount of insulation off the ends of nine of the one-meter wires, tin them, and solder them to the motors.
- After soldering each leadwire, inspect that the solder joint is smooth and shiny (not dull and rough, which would indicate a "cold solder joint" that won't conduct or hold well).

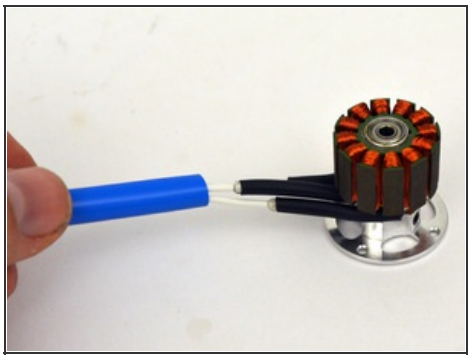
Step 12

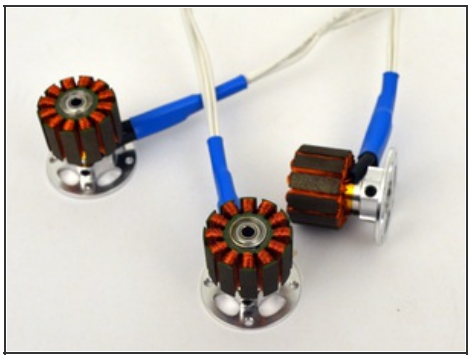




- Cut quantity 9 pieces of waterproof heat shrink tubing, length should be 2-3cm.
- Apply a small amount of hot glue to the joint as shown.
- With the hot glue still warm, slide the heat shrink tubing over the joint.
- Make sure the pieces of shrink tubing are slid all the way up the wires so that each solder joint is completely covered.
- Heat the tubing with a heat gun until the gel lining and hot glue inside oozes out from the tubing on both sides.

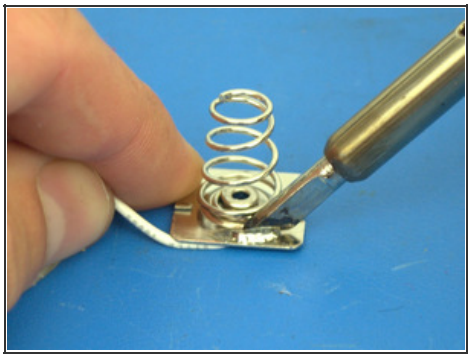
Step 13





- Cover the waterproof shrink tubing in each bundle with a 3 to 4cm- long piece of larger, regular shrink tubing.
- Shrink the larger tubing over the bundle of wires for each motor as shown.
- Repeat these steps until you have three completed motors.The motors are now ready!

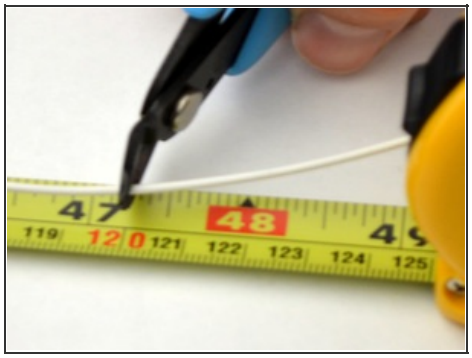
Step 14

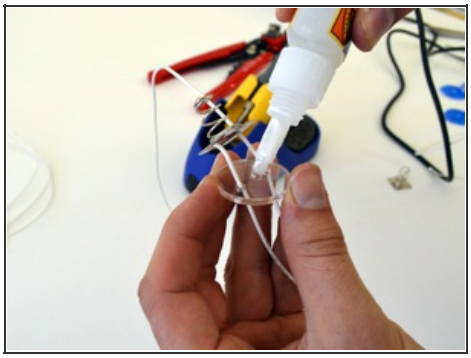


- We will now assemble the battery tubes.
- Use a medium grit sand paper to roughen a corner of the spring terminal. The spring terminal has two holes- one with a lip and one without a lip. You'll want to roughen one of the corners near the hole without the lip (the hole with the lip is better for allowing the wire leading to the other terminal to pass through without chafing)
- Melt a glob of solder onto the sanded area of the terminal.
- Strip and tin one of the one-meter wires, pass the stripped part of the wire through the hole without the lip, fold the stripped part of the wire onto the glob of solder you've made on the terminal, then solder the two together.
- The spring terminal has a fairly large thermal mass, so it may get quite hot before you can solder to it. To avoid getting burned, hold the terminal by the end of its spring or with pliers.

- Repeat these steps with an additional piece of wire on the second spring terminal.

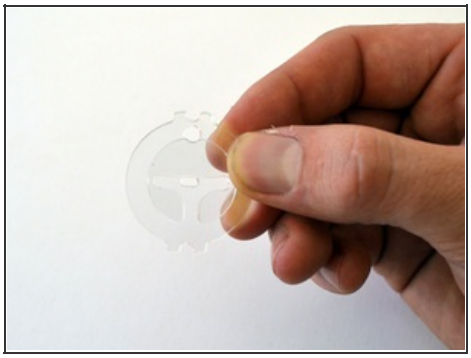
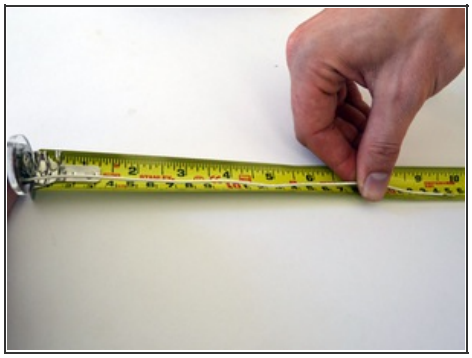
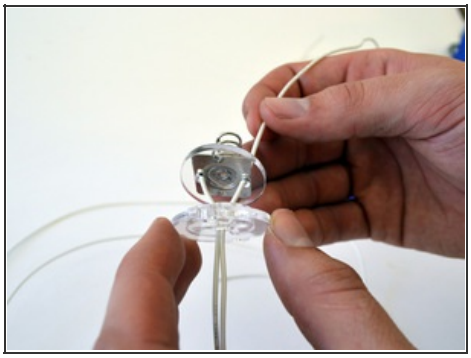
Step 15





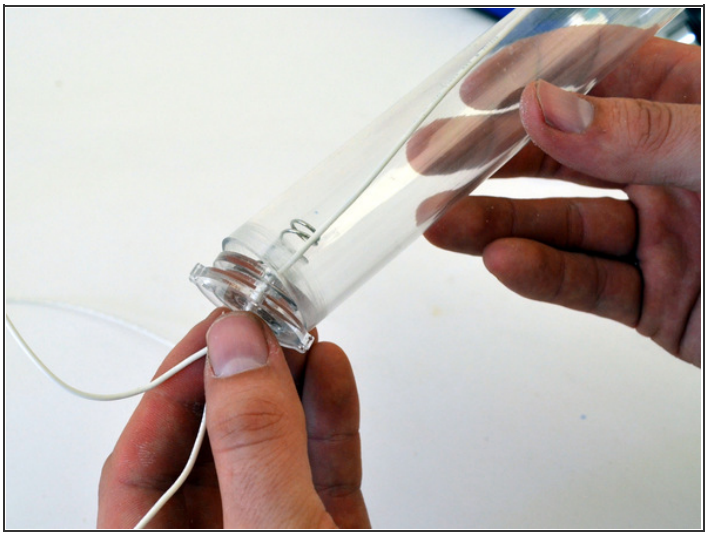
- Sand one side of the plastic disk with two holes (as shown). This will create a better surface for the spring terminal to bond to. Also roughen the bottom side of the spring terminal with sand paper.
- You'll need two longer lengths of stranded 20awg wire for the forward button terminals in each battery pack. Cut two lengths of wire that are each 120cm long.
- Thread the wire from the spring terminal through one of the holes on the sanded plastic disk, and the new 120cm-long wire through the other hole on the disk as well as the empty hole (the one with the lip) on the spring terminal as shown.
- Apply super glue (cyanoacrylate) to the roughened surface of the plastic disk. It's not a bad idea to wear rubber gloves when working with super glue so that way you can avoid getting it on your hands.
- The corners of the spring terminal will the be the part that actually contacts the plastic disk, so make sure you apply super glue to places those corners will touch.
- Place the spring terminal down against the plastic disk. Make sure the holes on the spring terminal align with the holes on the disk.
- Allow the super glue to fully cure and stop offgassing before moving to the next step. If you do not, then when you seal the spring in the tube then the vapor from the super glue will coat the spring and can cause a poor connection. (Your spring will look like it is white) Acetone and a paper towel on a stick can remove the glue from the spring.

Step 16

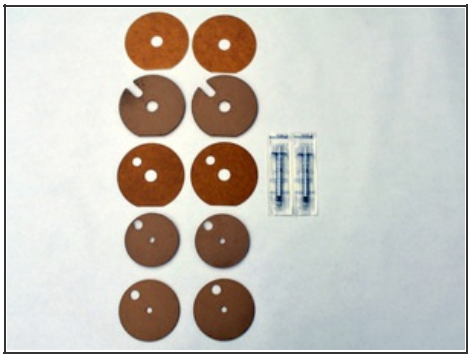
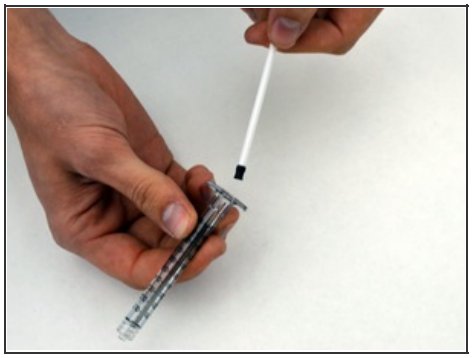
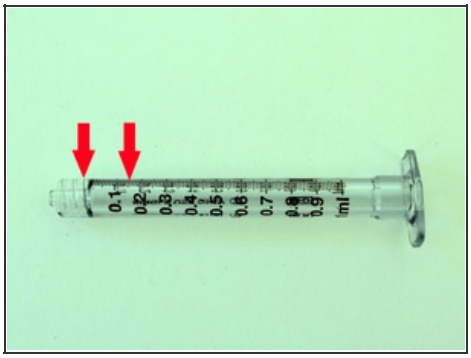
- Cement the outer (the largest one) and middle aft endcap disk (the C shaped one) together. Make sure that the rounded grove in the edge of the smaller piece is aligned with the hole on the larger piece, and the two disks are concentric.
- Before cementing the inner disk with the spring terminal to the two outer disks, pull the 120cm-long wire 26cm past the inner disk so that it will reach the forward battery terminal after passing through the battery tube (which will be attached later).
- With the wire extending 26cm from the inner disk, cement the middle and inner endcaps together (photo 3).

Step 17



- Sand ONLY ONE inner surface of each battery tube. This end will be the side that the aft (spring terminal) endcap assembly will be permanently attached too. (The other end must stay smooth so that the o-ring on the other endcap will seal against it)
- Place the aft endcap assembly into the sanded end of the battery tube. The fit will be snug. If you find it too hard to get the endcap assembly into the tube, you can use sandpaper to taper the edge of the endcap assembly to help guide it in straightly.
- A small amount of acrylic cement can be applied between the rim of the endcap and the battery tube. Although the two parts are different types of plastics (so the cement won't bond well), it should soften both pieces to create a seal that will help prevent epoxy from leaking out during potting (which will be done later).
- Once you've done this for both battery packs, you can set them aside (for the time being)

Step 18

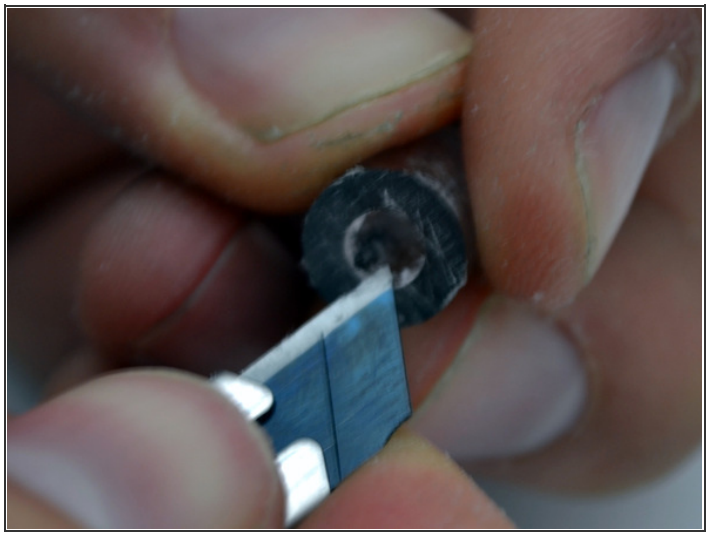




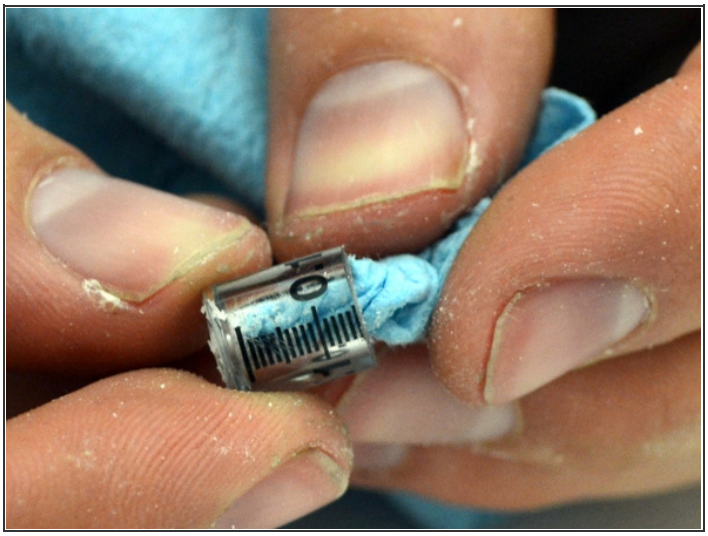
- We're now going to build the endcaps for the electronics tube of the ROV. Although the pieces for each endcap are identical, you'll want to build the endcaps so that they are MIRROR IMAGES of each other (we'll go into that in more detail later).
- Start out by removing the plunger from both syringes. We're going to cut the syringe tube in two locations to create a centering pin (which also acts as a purge valve) for the endcap pieces.
- Make sure to set aside the plunger in a safe place as this is needed to seal the electronics tube.

Step 19

- Cut the syringe just past its plunger stop (the barrier inside the tube that the plunger butts up against when pushed in all the way) with a hacksaw. We want to keep the plunger stop in place so that the plunger can make a seal against it during dives.
- We only want to cut off excess plastic (the part that a needle would normally screw into) in order to remove unusable length in the plunger.
- Once the end of the syringe has been cut off, cut at (around) the 0.16mL mark.
- Use medium-grit sand paper to smooth and square up the cut sides of the syringe.

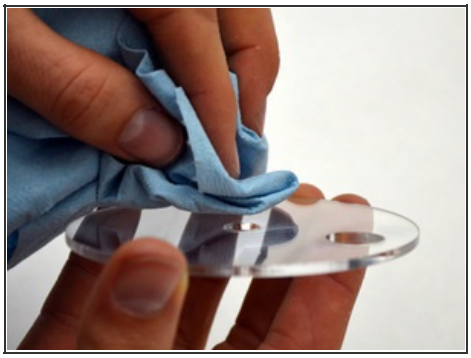
Step 20

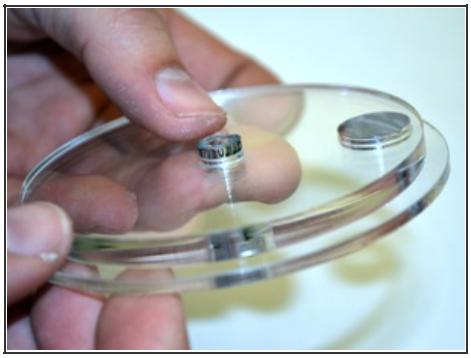




- Using a razor, you can debur the inside edge of the syringe section, but be careful not to make any large gashes along the inside surface!
- A paper towel or thin cloth can also be used to remove particles from inside the syringe tube.
- If you have a Q-tip handy, you can also use that (wetted with water or alcohol) to clean the inside of the syringe section.

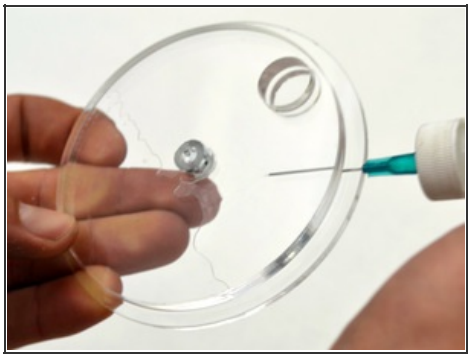
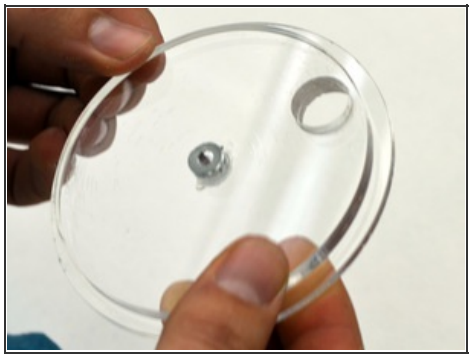
Step 21





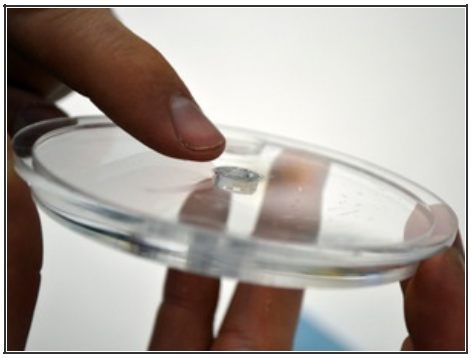
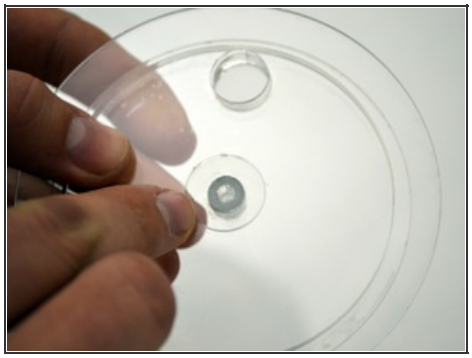
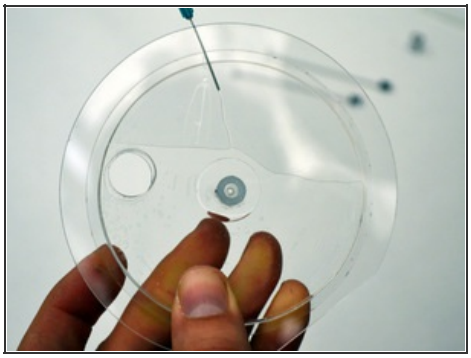
- Now we're going to start cementing the endcap disks together.
- The first two pieces you'll cement together are the 3mm-thick disk and the 6mm-thick disk with a smaller hole in the center.
- The 3mm-thick piece will end up being the inner-most disk of the endcap. Place the syringe section in the centering holes of the two disks so that the plunger stop-end of the syringe section is facing the inner disk.
- You may also notice small notches extending from one side of the inner disk (a result of the laser-cutting process). Ideally these notches should face inward (away from the 6mm disk) as they may make it harder for the o-ring to seal properly.

Step 22

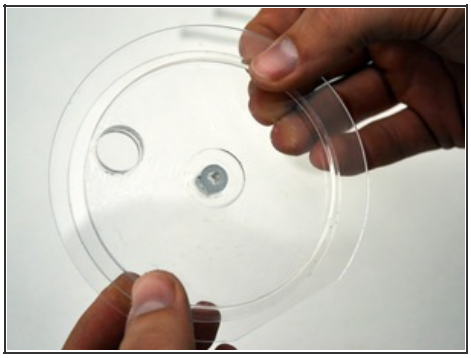
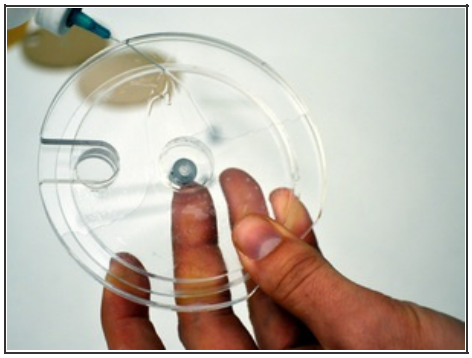
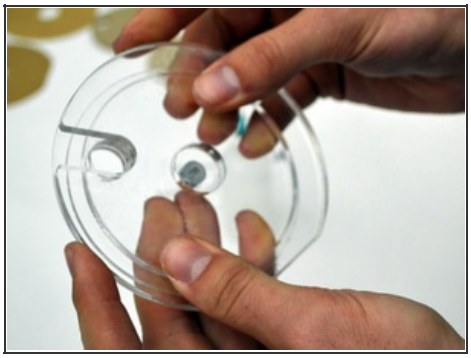
- To make the endcap as strong as possible, we'll want as much surface area between the two disks to be cemented as possible. A good technique for cementing the disks together is to insert the syringe needle between the top of the two disks while pinching the bottom.
- Allow cement to flow between the two disks so that it fills the gap between them from the bottom, up. (You may want to wear gloves, as some cement tends to leak out the bottom). Fill until the cement is about half way, then remove the syringe and squeeze the disks together so that cement is pushed across the entire interface between the disks.
- You may want to rotate the disks about each-other slightly to spread cement around, but be sure that the two holes toward the edges of the disks are aligned before the cement sets.
- Extra cement that drips out from the disks can be blotted up with a paper towel.

Step 23

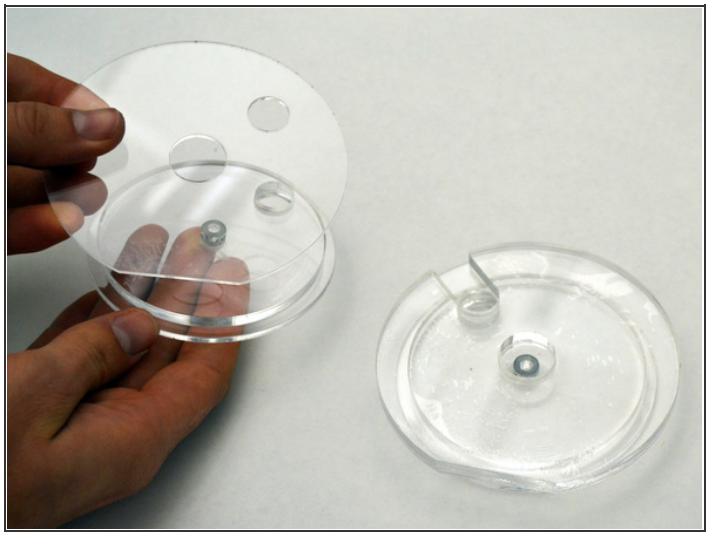
- Make sure the cut syringe is flush with the surface of the inner disk (the 3mm disk).
- Cement the clear, 1.5mm-thick disk to the 6mm-thick disk in the same way the first two were attached. Visually inspect to make sure the disks are concentric (since the hole on the 1.5mm disk is larger then the syringe section.)

Step 24

- Stack the remaining 6mm-thick disk (the one with a slot coming from the edge) on top of the 1.5mm thick disk that was just added. Make sure the inner radius of the slot and the hole from the other disks are aligned, and the disks are concentric.
- After the disks have been cemented together, it's a good idea to allow a little more cement to run around the perimeter of each interface to assure no gaps are left on the outside edges of the disks.
- One more disk (the white, 1.5mm-thick one) will be added later, but set that aside for now.
- Once these parts are cemented together, you can repeat the same steps for the other endcap.
- MAKE SURE THE ENDCAPS END UP BEING MIRROR IMAGES OF EACH-OTHER!

Step 25

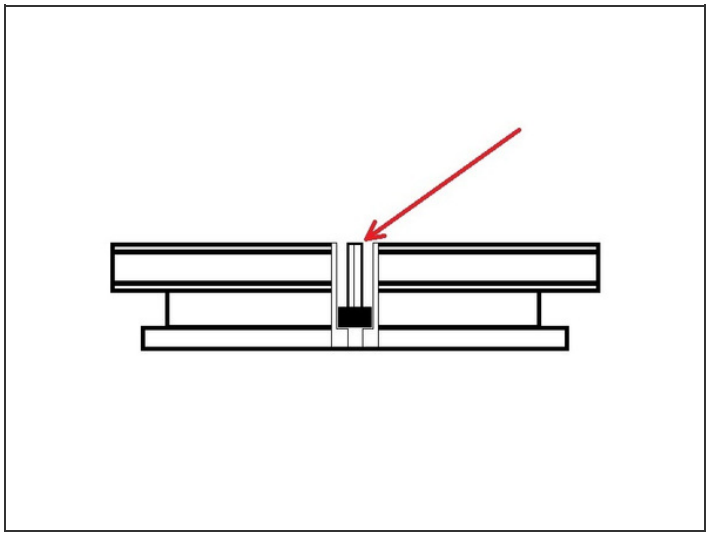


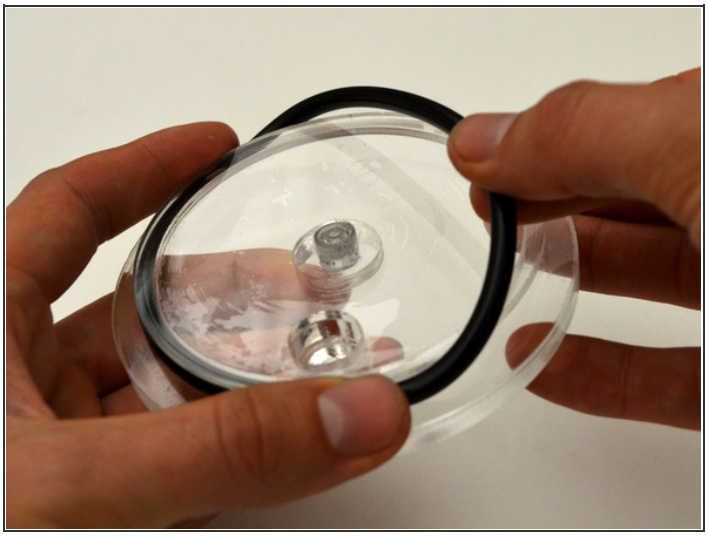
- Repeat the steps for building the previous endcap, but attach the 1.5mm, and second 6mm disks so that they make a mirror image of the other endcap.
- Make sure you cement the second endcap so it its a MIRROR IMAGE of the other (not identical) as shown.
- Congratulations! You have completed most of the electronics tube endcaps. Now, we'll check to see if they fit well in the main tube.
- Don't cement the white endcap flanges onto the endcaps yet!

Step 26

- In these steps, we'll check that the endcaps make a good fit in the Main Tube.
- Start out by beveling the inner edge of the main tube using a medium grit sand paper so that the o-ring will fit in the tube without getting damaged by the sharpness of the tube's inner edge. Wipe off all the dust left over from the sanding process when done.
- BE CAREFUL NOT TO SAND THE INNER SURFACE OF THE TUBE WHERE THE O-RING WILL BE. THIS PART MUST BE KEPT COMPLETELY SMOOTH. ONLY CHAMFER THE EDGE!

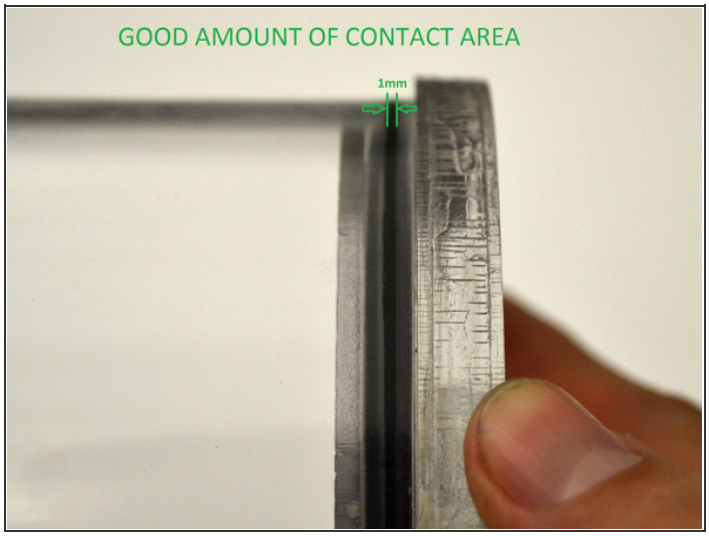
Step 27

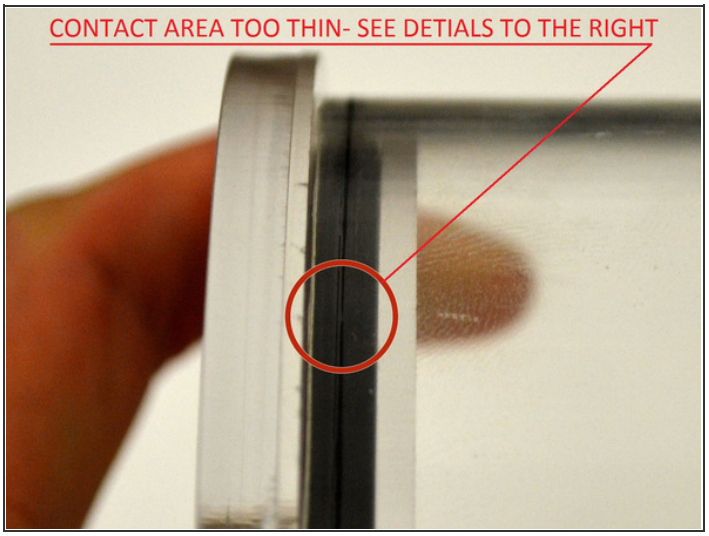




- We'll now place syringe plungers into the holes for each main endcap. These plungers seal the endcaps during use, but can be pulled out momentarily to relieve pressure after the endcaps get seated (which pressurizes the air inside the main tube)
- The stem of each syringe plunger should be cut so that it is flush with the outer surface of the endcap as shown. (This way it will be held in place when the main tube is placed inside the shell of the ROV)
- Place a #340 o-ring (the medium-sized, fat one) in the grooves ("o-ring glands") of both endcaps
- Since the o-ring will make a pretty tight fit with the main tube when pushed out to the right diameter, it is recommended that a lubricant be used on top of the o-ring (we like to use a commonly available lubricant called "MagicLube" which is available at many hardware stores) to assure the o-ring gets seated properly

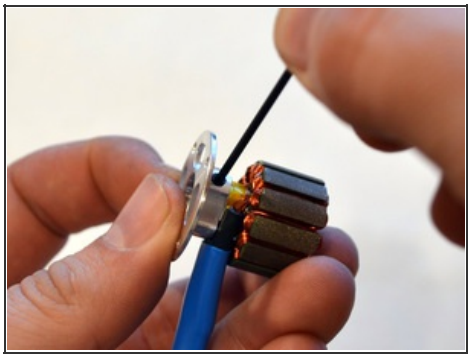
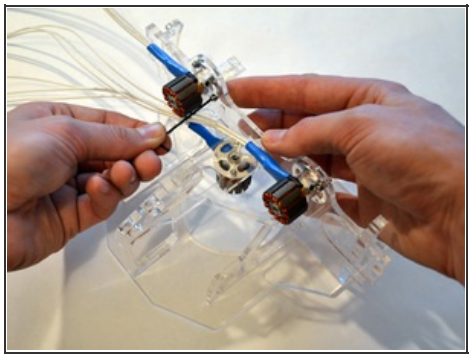
Step 28





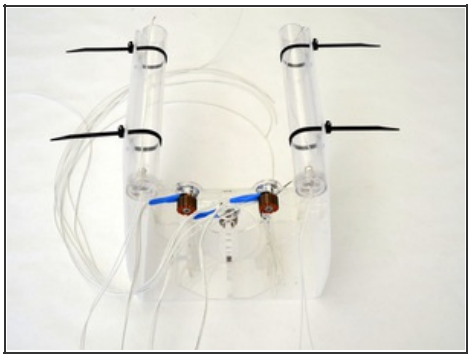
- Place both endcaps into the main tube, and inspect to make sure that at least a 1mm-thick band of the o-ring is pressed against the inside of the main tube. Rotate the tube to make sure the o-rig engages along the entire interior perimeter of the tube.
- VERY IMPORTANT: Because the tolerances of the pieces may vary slightly, it's possible that your endcap may not engage tightly enough with the main tube. (You can see an example of what this looks like in the second image).
- If the endcap doesn't fit well, the band of engaged o-ring will be very thin or may even disappear in spots. If this is the case, send us an email at info@openrov.com with an image of your endcap in the main tube (like the images shown) and we'll make sure you end up with parts that fit.
- Once you've tested the fit of your endcaps, put them in a clean place (like a zip lock bag) so dust and particles don't get on the o-rings.

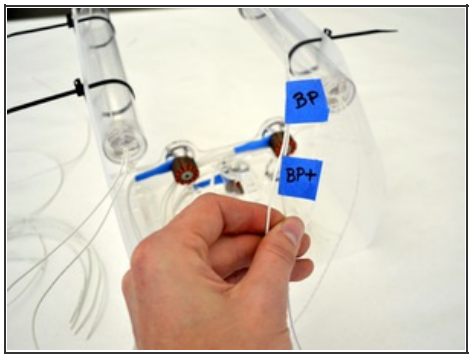
Step 29

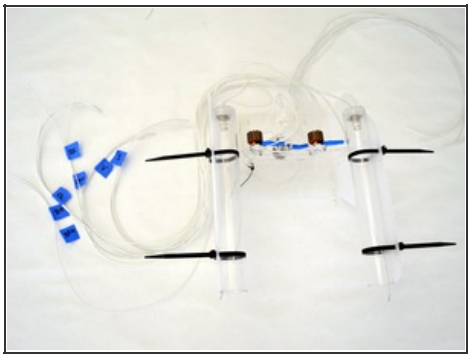



- Tighten the (M1.5) set screws on each motor mount, as seen in the first picture. In order to make mounting easy, mount the bolt so that the nuts are on the opposite side of the frame as the motor.
- Attach the motors to the inner structure using M2 screws, lock washers, and nuts. It is easiest to mount the vertical motor first. The motor leads should go to the left of the upside-down internal structure (which will actually be the right or "starboard" side of the right-side-up ROV.
- If you need to adjust where the wire is coming from the motor, you can loosen the M1.5 set screws, make the adjustment, and then tighten them again.
- Now take the six auxiliary wires that you cut in step 11 and mount them to the frame underneath the forward/backwards motors with a zip-tie.
- If you don't have any small zip ties laying around, you can find some in the boxes for the Electric Speed Controllers

Step 30

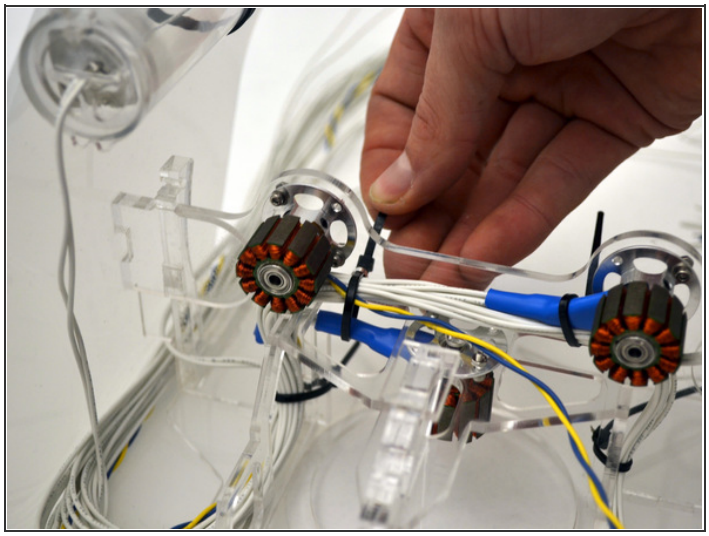


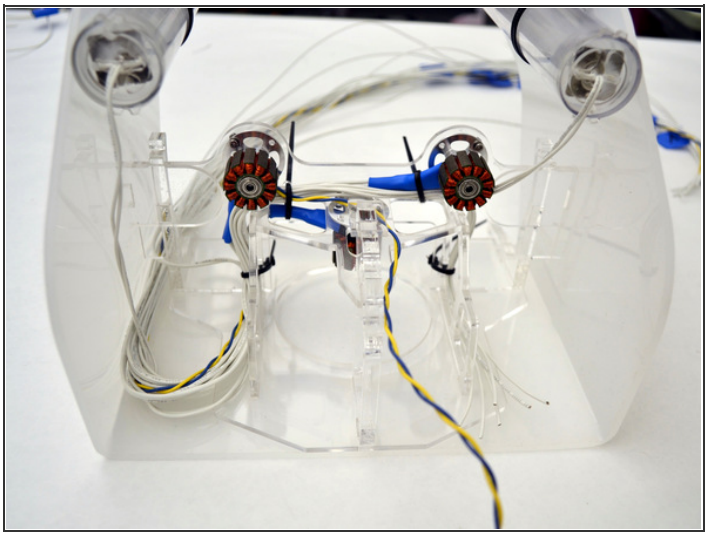




- Insert the internal frame into the outer shell, and using four large reusable zip ties, mount the battery tubes as shown.
- Because "left" and "right" are relative terms (they depend on which way you're facing), ships and other vessels often use "port" and "starboard" which are always the same side, regardless of your own orientation. When you're facing forward (and upright) "port" is on the left side, and "starboard" is on the right side.
- Label the three-wire bundles coming from each motor. We use "P" for the port (left when upright) motor, "V" for the vertical motor, and "S" for the starboard (right when upright) motor.
- Now label each of the battery packs. (We use "BP" for "Battery- Port" and "BS" for "Battery- Starboard". You'll also want to trace the longer wire on each battery pack (the one that goes all the way to the front of each tube) and label them "BP+" and "BS+", respectively, so that you can later identify the polarity of each wire.

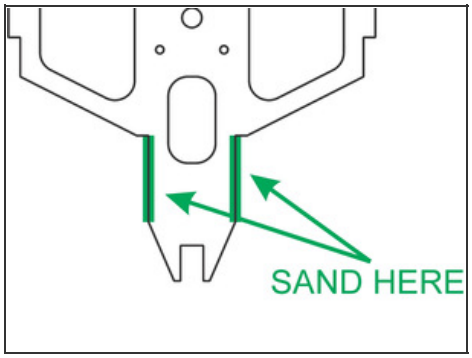
Step 31

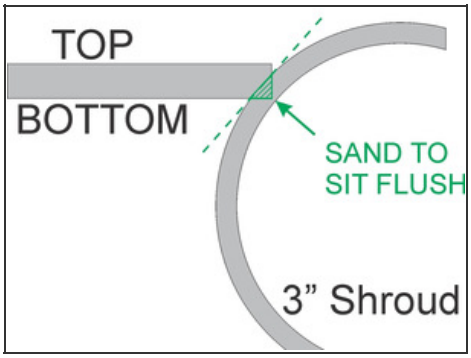




- Now we are going to do some wire management.
- First take the tether wire, the twisted pair of two colors, and run it so its length matches that of the wires connected to the motors. It should run in the middle by the handle, as seen in the picture.
- Secure all of the wiring bundles with zip ties as shown. You can find small zip ties in the boxes for the Electric Speed Controllers. (Note that in this image, you can see I decided to point the bundle coming from the starboard motor downward instead of its original orientation where it was pointing to the left)
- The collective bundle of wires (we'll call it the main wiring harness) should snake around in a loop as shown. This will make it so less precise measuring is needed when running the harness through the endcap, and will also allow for motors to be replaced more easily in the future.

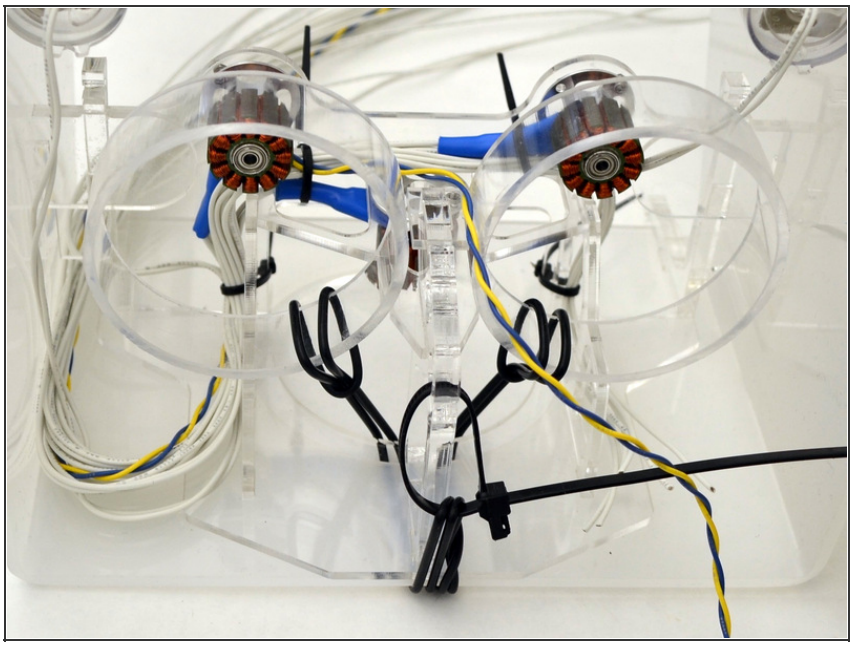
Step 32





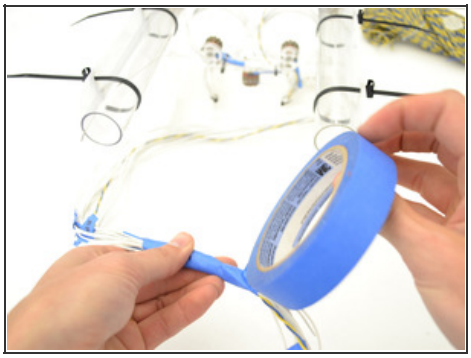
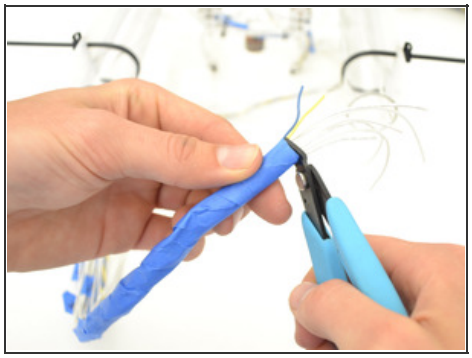
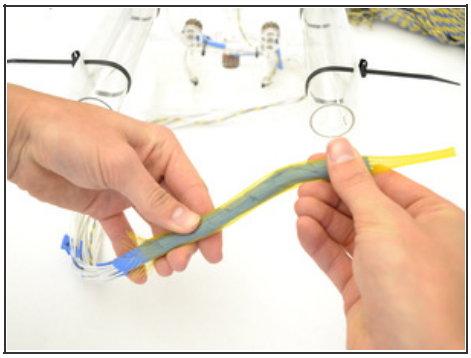
- It's now a good time to fit the 3" diameter propeller shrouds.
- First, sand the edge of the horizontal shroud support to create a chamfer that the shroud can rest against. We'll want to maximize the contact surface area between the shroud and its supports so that it can be attached firmly.
- Quite a bit of material will need to be removed for the shroud to fit properly. Although the photo shows a piece of sand paper being used to create the chamfer, a file or even a Dremel tool may be more appropriate. When you are done, the shroud should rest on three different mounting points at once.

Step 33



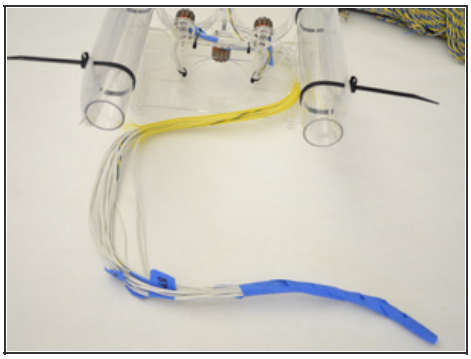
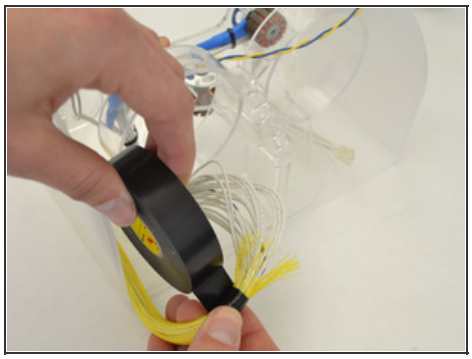
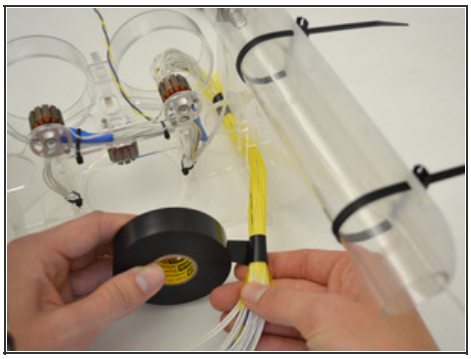
- Now we'll cement the shrouds in place.
- Place one of the shrouds against the supports as shown. You can use the orings to hold them in place...but you can also hold it in place with your finger.
- You'll want to inspect the three points where the shrouds interface the internal structure. If the center "horizontal shroud support" was not sanded down enough, it may prevent the shroud from touching all three edges. If this is the case, it can be sanded down more with sandpaper or a file.
- Apply cement to all three edges where the shroud interfaces with the internal structure on both sides.

Step 34

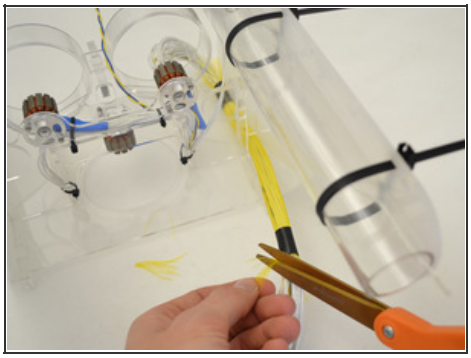
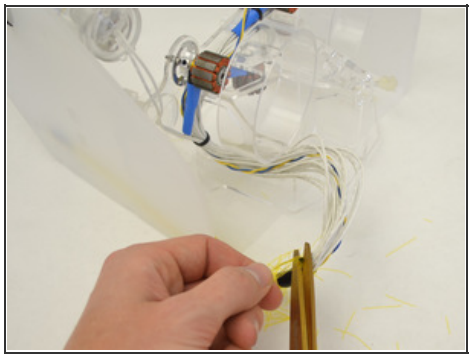
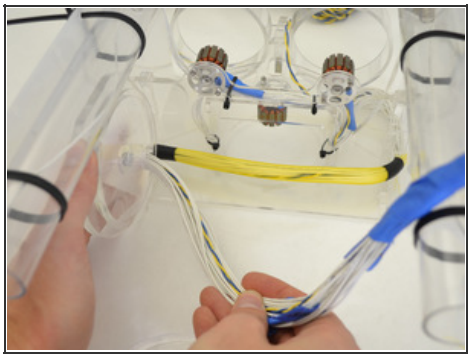
- Now we're going to route the yellow mesh sleeve material over the main wire harness. The sleeve material expands when it is compressed much like how a finger trap works.
- Start by wrapping tape around the ends of all the wires in the main harness as shown. The purpose of this is to prevent the sleeve material from getting snagged as it is placed over the harness.
- If only a few individual wires are left sticking out of the tape, and their labels are further down the wire, those ends can be snipped off.
- Push the sleeve over the main wiring harness and slide it all the way down until its end goes past the bulkhead of the internal structure.

Step 35

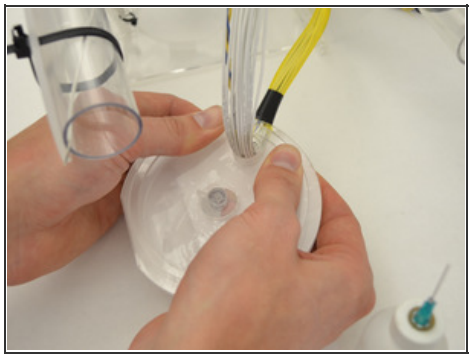
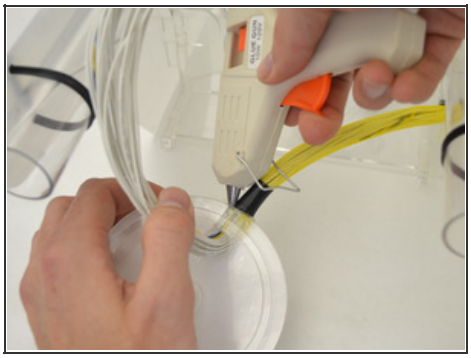
- To keep the sleeve material from fraying (beyond what it will have already done while putting it on) wrap both ends with electrical tape where the fraying stops.

Step 36

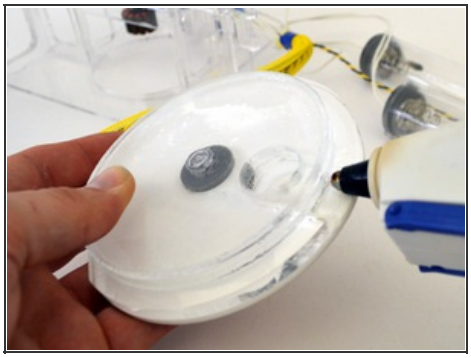
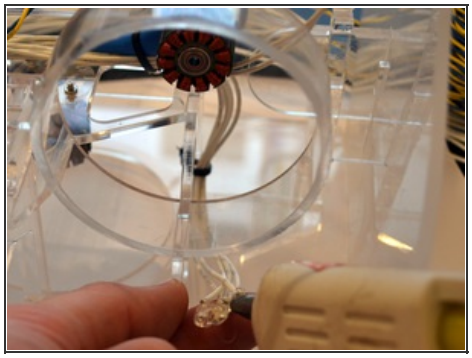
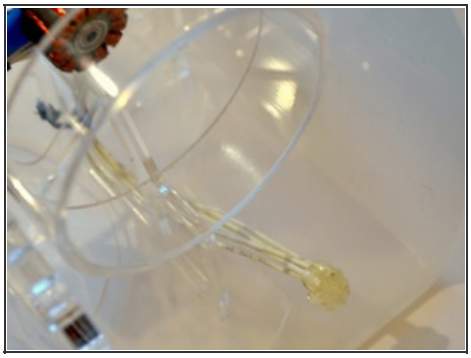
- Use scissors to cut off left over frayed ends of the sleeve material up to the electrical tape.
- Thread the wiring harness through the Port endcap. The harness should go from the outside of the endcap, inward. You can make sure you're going through the correct endcap by placing it in the position as shown. In this position, the flat edge of the endcap should face toward the port battery tube.
- During this step, we'll measure out the right length of the wiring harness so that it is not too tight or too loose when the end cap is in place. Adjust your wiring harness and end cap so that they resemble the photo above.

Step 37

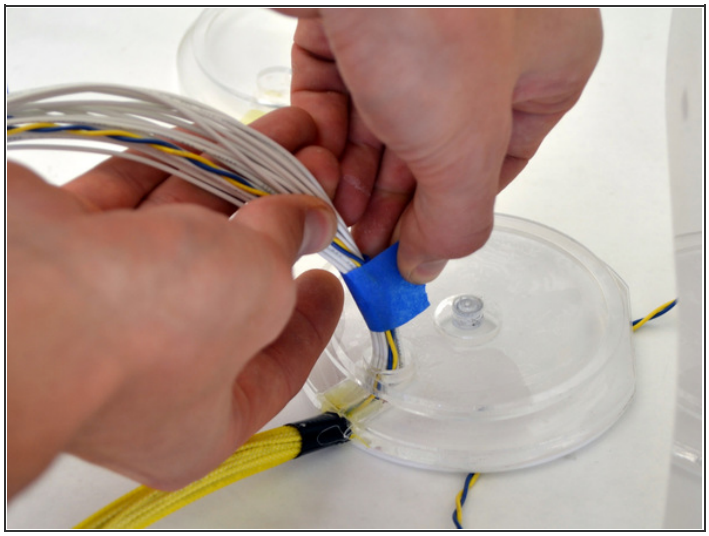
- Once the tension of the main wire harness looks good, you can cement the white endcap cover onto the endcap. Be sure the endcap cover is pressed firmly against the endcap near where the harness passes through the assembly.
- You'll also want to cement the other white endcap cover onto the other (Starboard) endcap.
- Apply hot glue around the part of the endcap the wire harness enters through (the side with the rectangular opening- not the side with a circular opening). This hot glue will form a barrier that will prevent epoxy from leaking out when the endcap is potted.

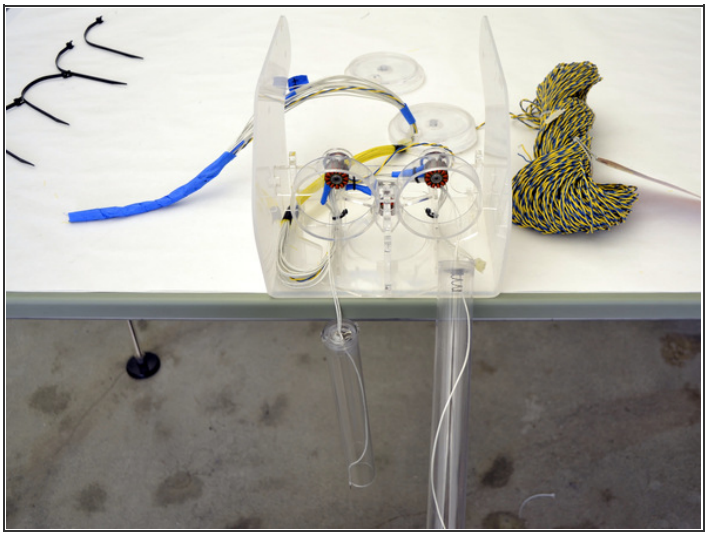
Step 38

- The other (starboard) endcap can also be prepared for potting at this time. Create a barrier of hot glue at the end of the endcap channel to hold the epoxy in.
- Apply a glob of hot glue to the end of each of the six auxiliary wires, then after each glob has hardened, bundle the ends together and apply hot glue to the bundle.
- The six auxiliary wires can be used later to attach external payloads like sensors and actuators. While these are not being used, the ends should be sealed so water can't travel down the wires underneath the insulation into the the electronics tube (an effect known as "hosing"). To prevent this, we'll seal the ends of the wires with hot glue.

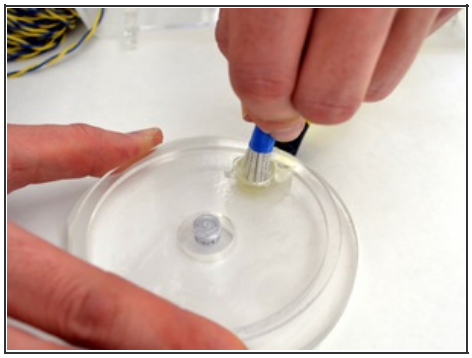
Step 39





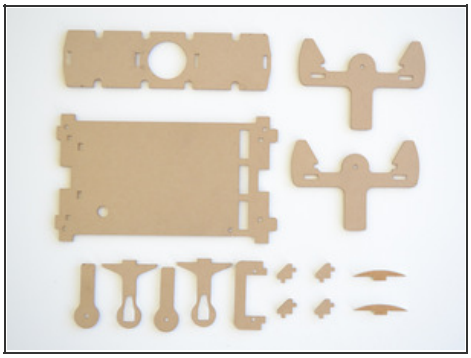
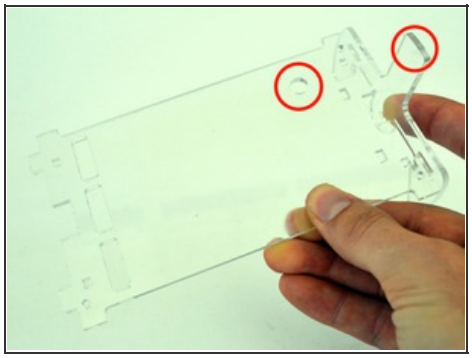
- Now, we're going to prepare the endcap to be potted. To start, we'll want to bundle the wires coming out of the endcap together.
- We'll also pot the two battery tubes during this period. The tubes can be dangled over the edge of a table from the internal structure as shown (so that the epoxy they are potted with doesn't flow out the hole it is injected into)

Step 40



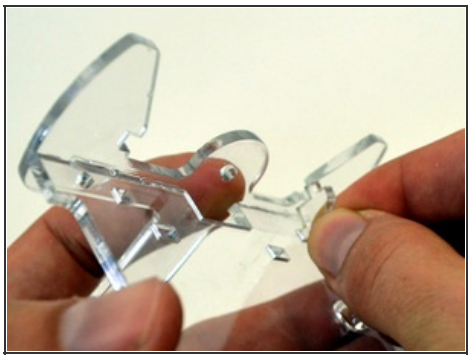
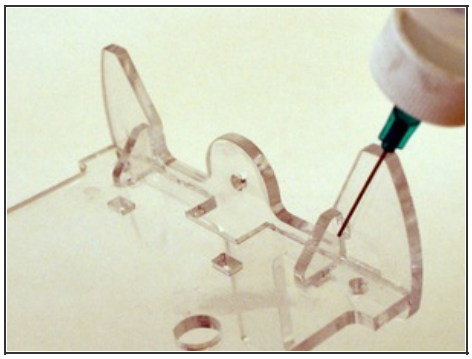
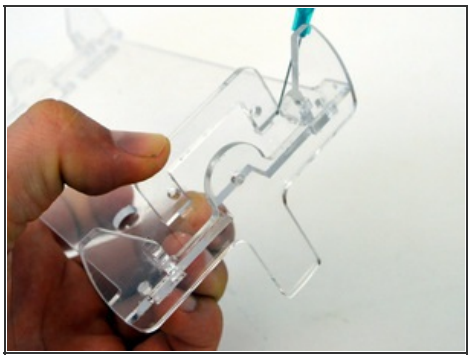
- You can now start potting the endcap. It is important that all the gaps between the wires in the harness get filled with epoxy. When potting the harness, periodically insert the epoxy nozzle between random sets of wires and move the tip of the nozzle around. Also be sure to inject epoxy under the channel the wires pass through in the endcap.
- To help remove voids in the epoxy filing the endcap channel, move the harness up and down (like a toilet plunger) and from side to side. This may cause the level of the epoxy to fall (as it fills voids). More epoxy can be added as needed.
- Now we pot the aft battery endcaps. To do this, we'll insert the nozzle from the epoxy cartridge into the small hole on the edge of the endcap. Injected epoxy should flow in both directions around the perimeter of the endcap, then into the channel leading toward the leadwires and out to the channel's two ends. Some may also ooze out the center.
- Finally, you'll also want to fill the hole of the Starboard endcap with epoxy. Just as for the Port endcap, epoxy should come up to just below the rim of the endcap hole.

Step 41

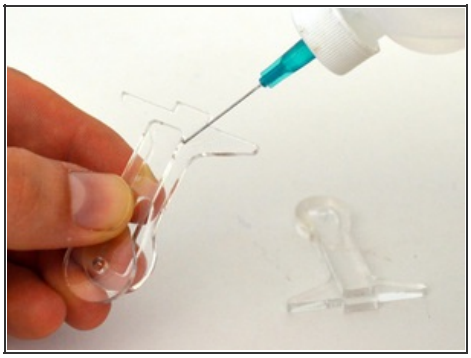
- While the potting on the endcap and the battery tubes is drying, we are going to move on the the electronics.
- The first step is to build the Electronics Chassis (also known as the E-Chassis). For this, you'll need the 15 parts shown here (note that if you are building from a kit, the two crescent-shaped blinder pieces in the lower right of the photo may be in a different bag)
- Start by cementing the Endplate pieces to the Main Platform. Orientation is important here: the large hole on the Main Platform should be in the upper right corner with center stand-off on Endplate pieces pointing toward you (as shown). This will allow the OpenROV Controller Board to fit on the right way.

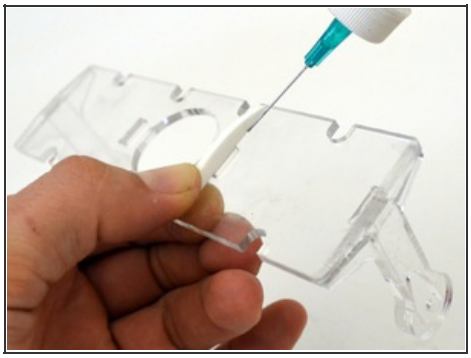
Step 42

- Now attach the four Braces (two for each Endplate) to the E-Chassis. They should be able to fit in if inserted at an angle and with aggressive force.
- Next, cement the Servo Mount to the same side of the Main Chassis the Braces are on.

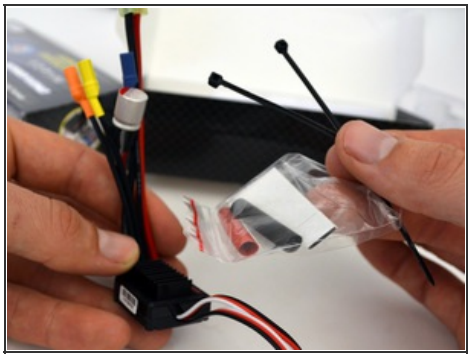
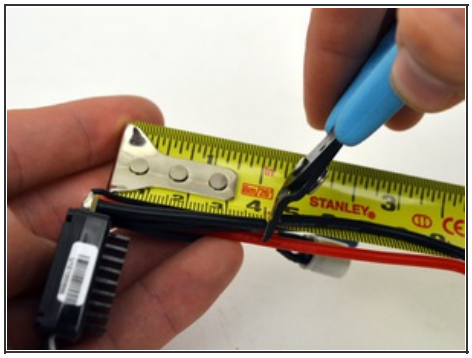
Step 43

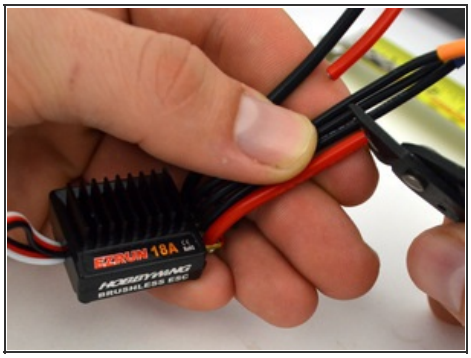




- Now we'll start making the camera platform. Start by cementing the two pieces for the Camera Mount arms together. The round bases of each piece should end up being concentric, but to aid with cementing, it may be easier to stagger the pieces initially. Of course, be sure to align them before the cement sets!
- Next, you'll want to cement the Camera Mount arms to the Camera Platform with the smaller of the two pieces on each arm facing outward.
- Finally, attach the white blinders to either side of the camera hole.

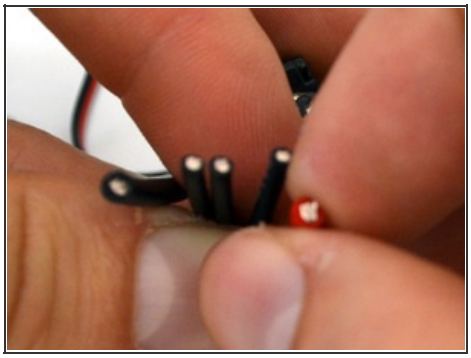
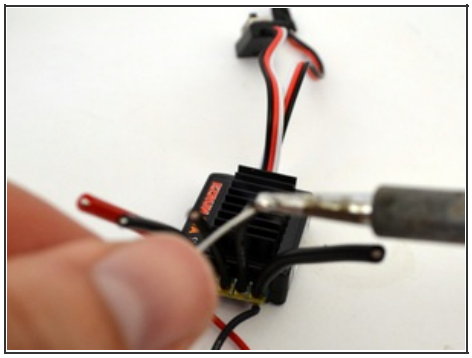
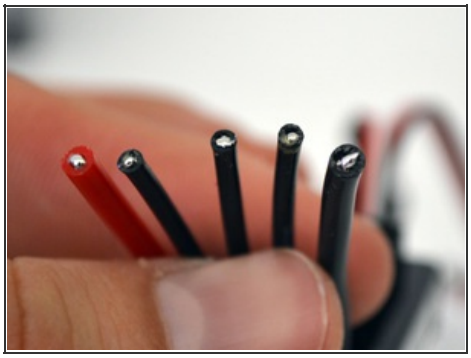
Step 44



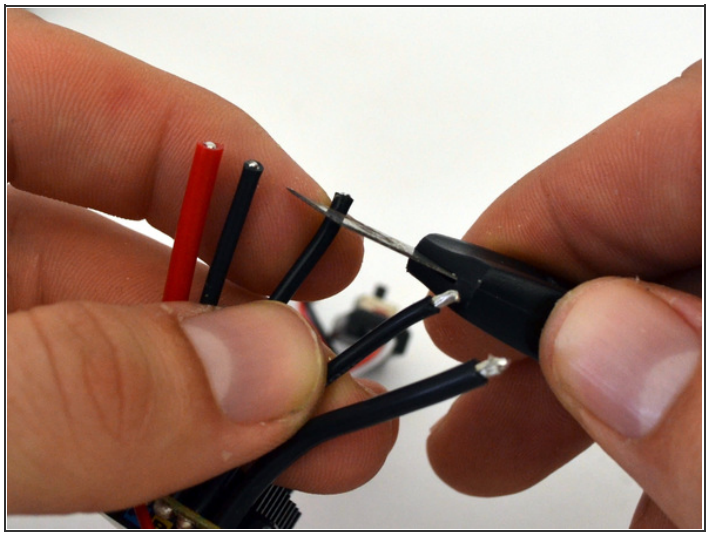
- Now it's time to attach the ESCs to the OpenROV Controller Board. In each ESC box, you'll find one ESC, two zip ties (which you probably used earlier), and a bag with shrink tubing and double-sided adhesive. You'll want to keep the zip ties and bag, so put them aside for now.
- We'll want to cut the thick lead wires from the ESC down to a length of 4cm (Don't cut the thin capacitor wires). To keep everything looking tidy when mounted to the Controller Board, it's best to start by cutting one of the lead wires to the right length, then use that as a guide to cut the others afterward.

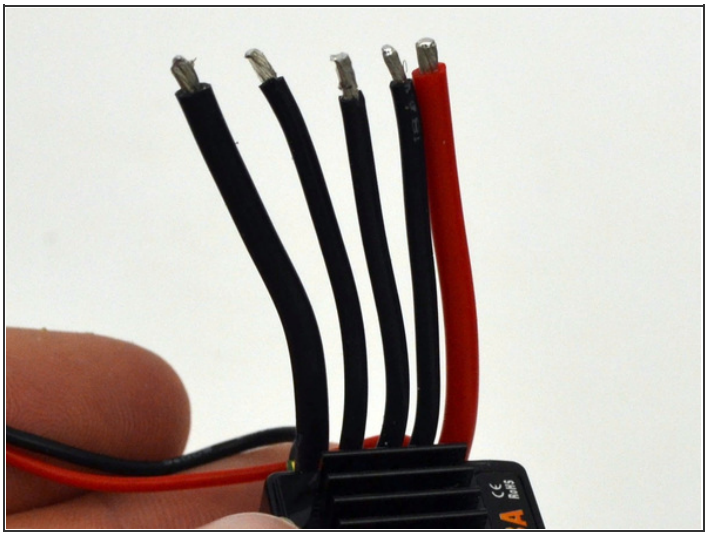
Step 45

- Next, we'll want to roll each wire around between our fingers to make the cross section of the wires circular. This will be important later on (especially with the two power wires) for getting them to fit into the holes on the Controller Board.
- Because each wire has a very high strand count (and thus the strands are very fine), we'll do a trick to prevent them from fraying. Using a soldering iron, heat the tips of each wire (which is not yet stripped) and apply a bead of solder. The silicon insulation on the lead wires should be able to take the heat.
- You should end up with five wires that have small beads of solder covering their strands as shown.

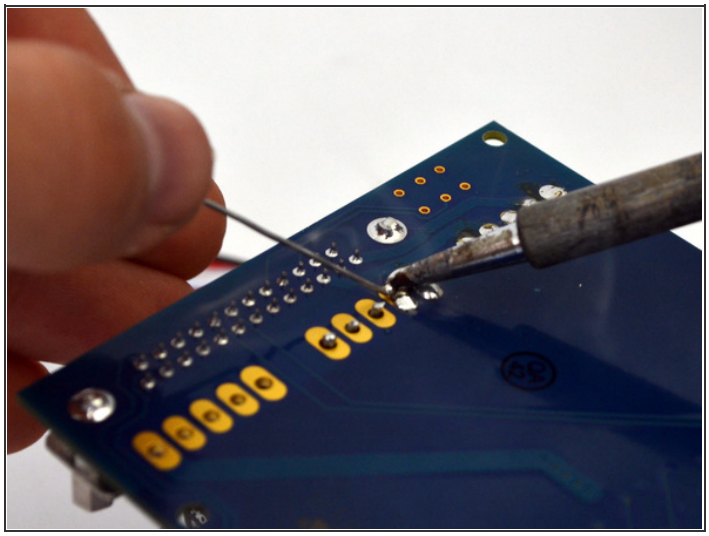
Step 46

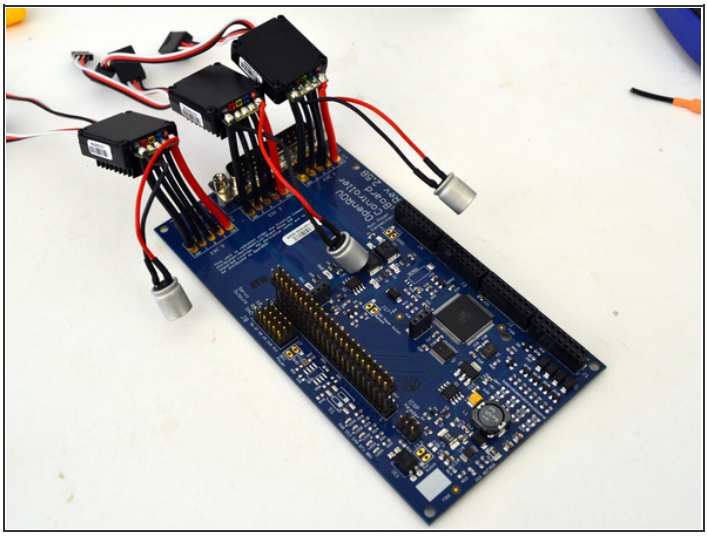




- You can now strip each wire. Strip off 4mm of insulation from each wire using a sharp razor (auto-strippers will not work well with the flexible silicon insulation and the short cut length). Repeat this entire process two more times until you have three ESC's that are cut and soldered.
- The ESCs should now be ready to be mounted to the Controller Board.

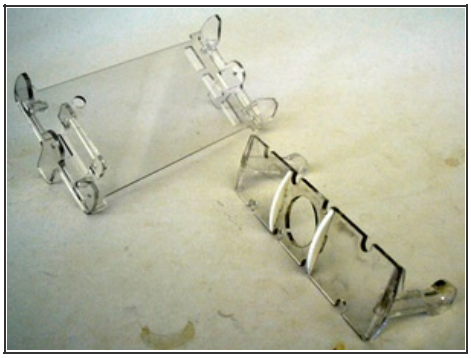
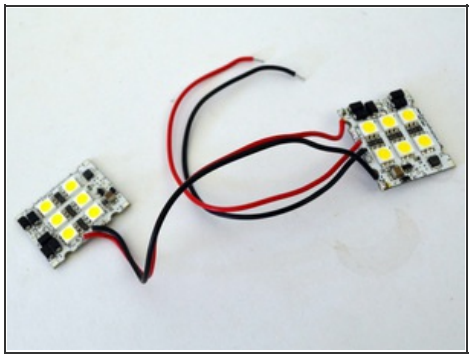
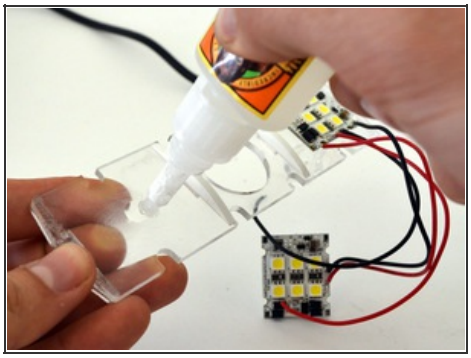
Step 47





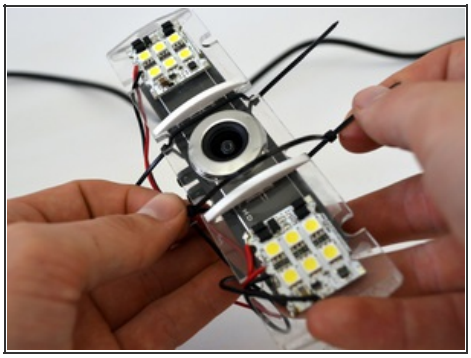
- The ESCs will ultimately be placed over the blank area of the Controller Board with the leadwires arching over to the holes they'll be soldered in. Look at the second photograph in this step to make sure you've got them oriented correctly.
- Insert the ESC leadwires into the holes on the Controller Board and solder them in place. You'll want your soldering iron to be at a fairly high temperature since there is a lot of metal to sink heat here.
- Watch out for stray wire strands that don't make it into the Controller Board holes. These can be removed with small wire cutters or needle-nose pliers.
- Once all the ESCs are soldered in place, it is recommended that any excess wire lead that protrudes beyond the solder joint be removed using diagonal cutters.

Step 48

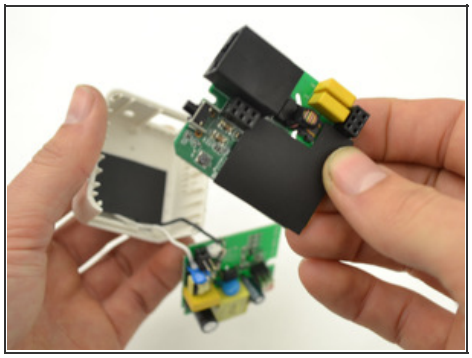
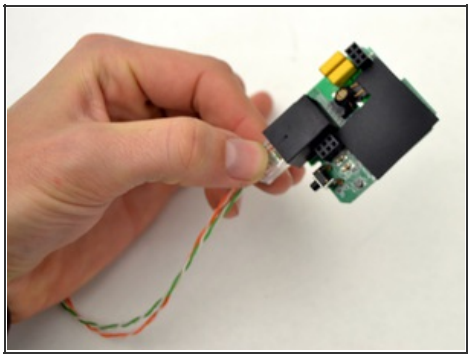
- Now you have both parts of the E-Chassis and a controller board that's ready for external electronics. Nice job! Next, we're going to attach the lights and camera to the Camera Platform.
- Start by soldering the two light panels together. To do this, you'll want to create a small solder blob on the pads on the far left and right of one of the light panels, then attach the leads from the other light panel so that the red wire you're attaching is on the same side as the red already-attached wire (and the same for black).
- Apply a small amount of super glue between the two notches in the Camera Platform and place a light panel there. The light panel should be positioned so that its leadwires are aligned with one of the notches, and it should be centered vertically.
- If the light panel is too high or too low, the electronic components on the panel may rub against the Electronics Tube.

Step 49



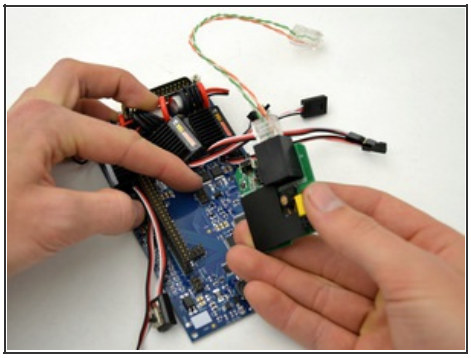
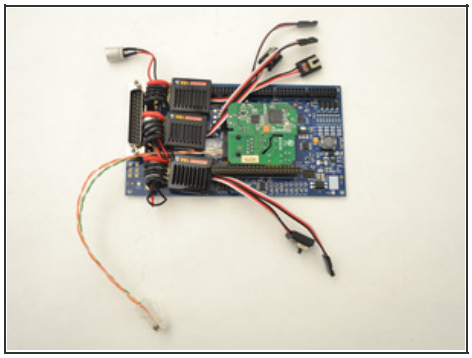
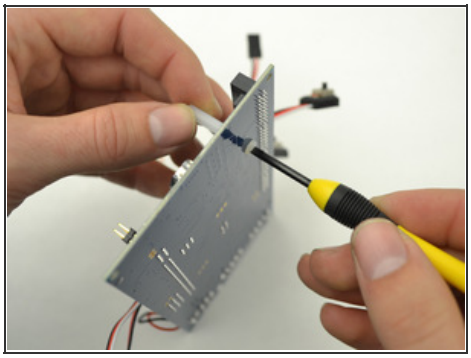
- Now you'll want to take apart the Genius F100 webcam so it can be mounted to the Camera Platform. Start by pulling the camera off of its stand (a strong tug should do the trick)
- Next, remove the plastic piece still attached to the camera by unscrewing the small Phillips-head screw that goes through it.
- Using small zip ties (you'll have found two of these in each box the ESCs came in), attach the webcam to the Camera Platform as shown. You'll need to double up the zip ties in order for them to reach around the assembly.
- This is also a good time to focus the camera. Even though you don't have the ROV connected yet, you can connect the camera directly to a USB port on your computer and open a program to view its video feed. Focus the camera on a distant object by rotating the bezel surrounding the lens.
- You can use scissors or a diagonal cutter to remove excess zip tie material. You'll want the zip tie heads to be positioned so that they don't bump into the E-Chassis main platform when the Camera Platform is looking all the way up or all the way down.
- Once everything is secure, you can set the Camera Platform assembly aside for later.

Step 50

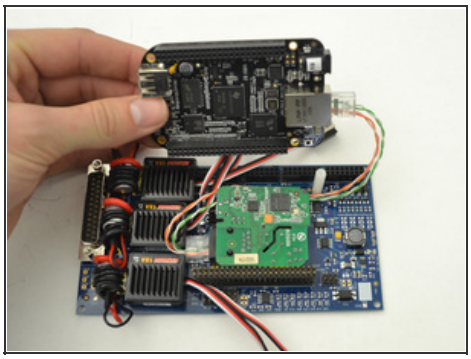
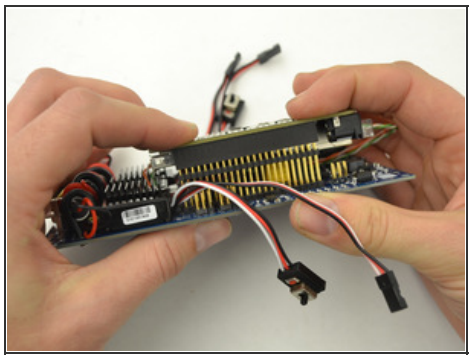
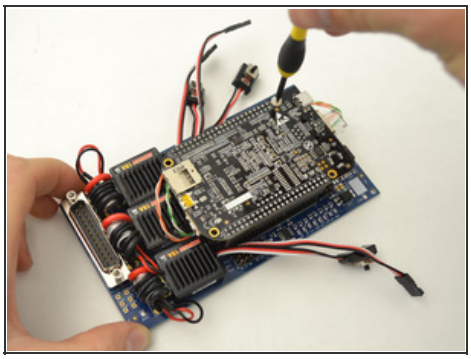
- Now we will work on the ROV side Ethernet conversion.
- First, pry apart one of the Homeplug adapters using a flathead screwdriver. It's easier to pry using a twisting motion then a lever motion. Keep in mind that one of the four walls of the enclosure is attached to the top piece, so prying wont work on that edge.
- Once you've opened the Homeplug enclusure, pull the top circuitboard (the one with the power wires going to it) off of the communication board below it. You can discard everything but the communication board.
- Because this board will be mounted very close to other electronics, you may want to cover the bottom of the board with electrical tape (to help prevent anything from accidentally short-circuiting). This step isn't crucial since the spacing of the boards is designed with sufficient clearance, but it doesn't hurt to have a little extra protection
- Attach the ethernet jumper to the communication board as shown.

Step 51

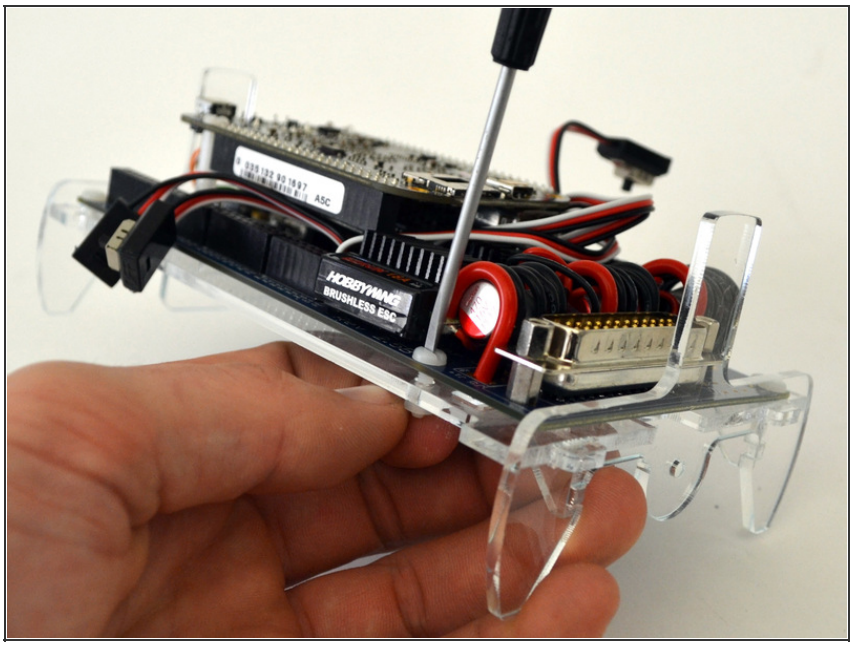
- Place the communication board on the controller board using two 6-pin reciprocal headers. With the ESCs mounted, it will be a tight fit go get everything on, but with a little finagling, it will all fit.
- Attach the nylon standoff to the hole toward the center of the controller board using a nylon M3 screw as shown.

Step 52

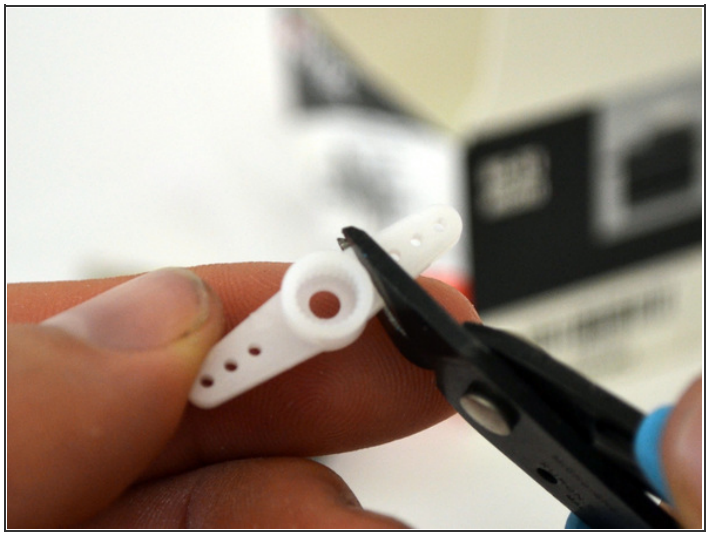
- Lay the ESCs down on the Controller board as shown.
- Plug the other end of the Ethernet jumper into the BeagleBone Black as shown. Ultimately, the Ethernet jumper wire will snake around the side of the Homeplug adapter board near the standoff.
- Press the BeagleBone Black onto the extended header set on the Controller Board as shown. Make sure the header pins on each board are aligned with each-other properly!
- Secure the BeagleBone Black to the nylon standoff using an additional nylon M3 screw.

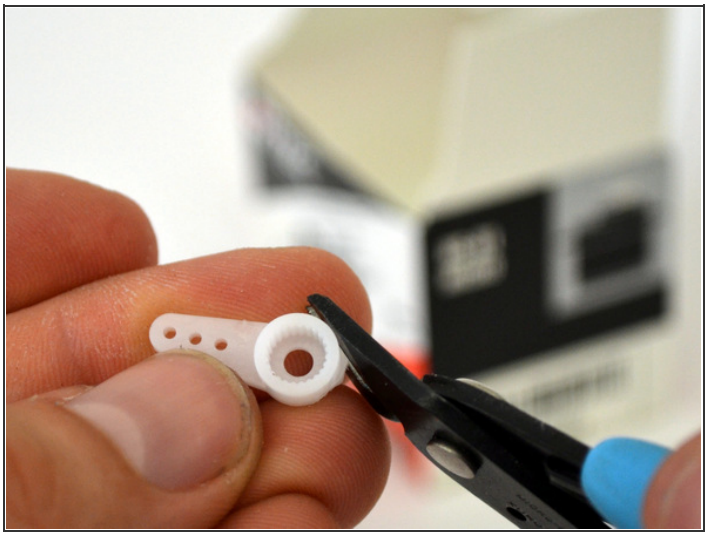
Step 53



- Attach the Controller Board to the E-Chassis using M3 nylon screws and nuts as shown. To orient the board, assure that the three rectangular cut outs on the E-Chassis are aligned with the three groups of solder joints from ESCs on the Controller board.
- For the screw hole closest to the DB-25 connector, the ESC near the edge may need to be lifted slightly to put the screw in place.

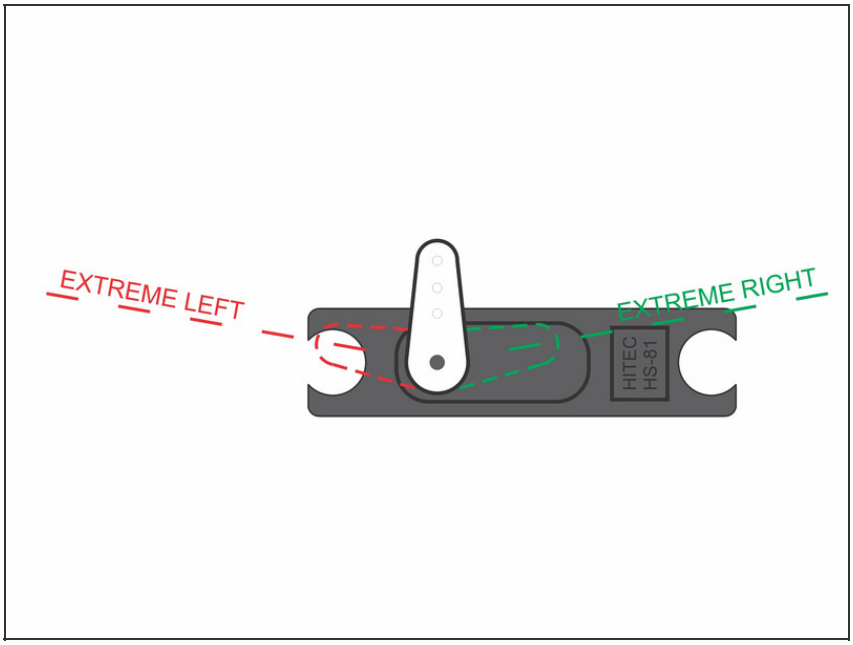
Step 54





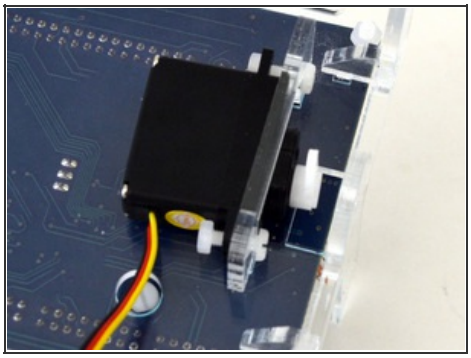
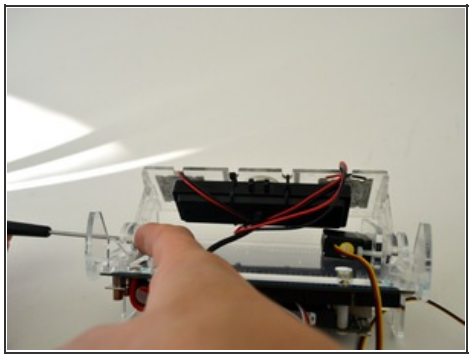
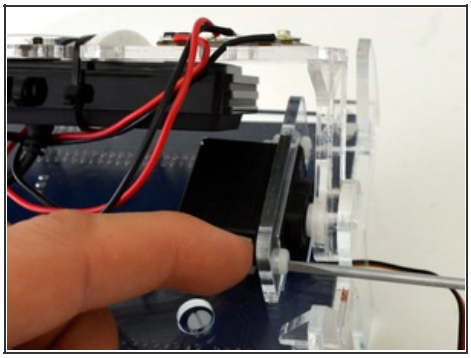
- Take the two-arm servo control horn (in the same box as the HS-81 servo) and cut off one of its arms using a diagonal cutter.
- Also use the diagonal cutter to remove the corners from the cut-off portion of the horn. This will allow the arm to fit inside the hole cut out in the Camera Mount arm.

Step 55



- Before mounting the servo to the E-Chassis, make sure the horn (white plastic part) is centered.
- To do this **gently** rotate it back and forth to its extreme left and extreme right. You can remove the horn and then adjust how the horn is placed on the servo so that it centered between the extremes. (see diagram).

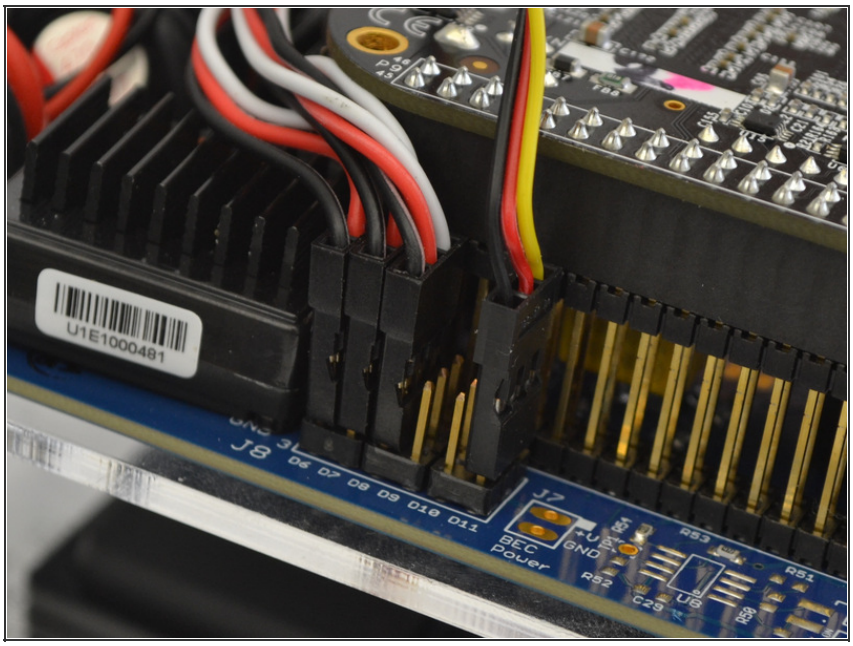
Step 56

- Loosely attach the servo to the E-Chassis using a set of M3 screws and nuts as shown. You'll need the nuts to be just barely threaded onto the screws at first so that the Camera Mount arms can be put into position before being secured. (Make sure the arm is centered - lined up with the camera mount semi-circle.)
- Place the Camera Mount Assembly onto the E-Chassis so that the top of the webcam (the side without the webcam mounting stand tabs) is facing up with servo on the right when the camera is facing toward you.
- Attach the arm on the side without a servo to the E-Chassis using an M3 screw and nut.
- Do not fully tighten as this screw will act like a hinge and should not create much friction.

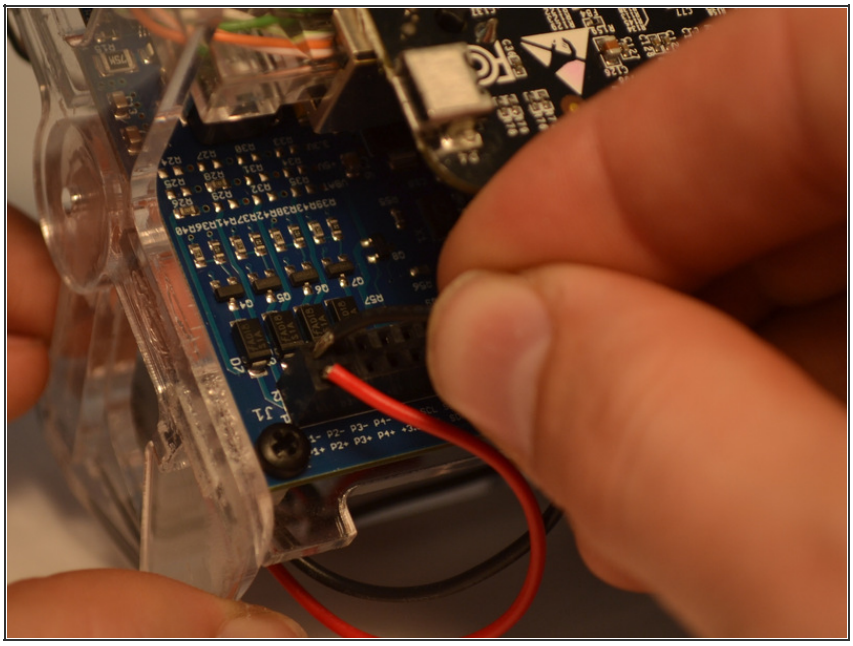
- After assuring the servo arm is seated inside the cavity of the Camera Mount arm, tighten the two screws holding the servo in place until they are snug.

Step 57



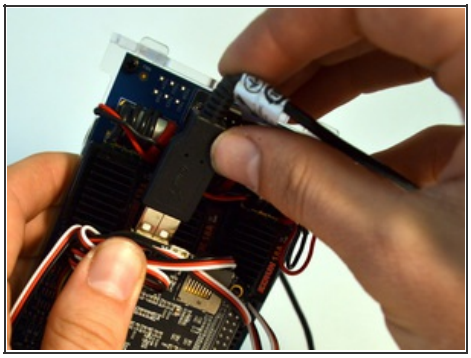
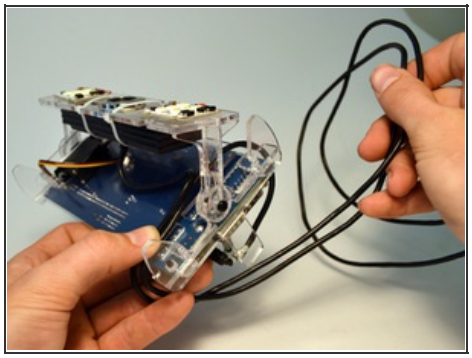
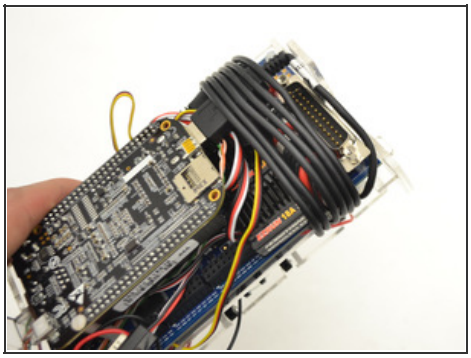
- Plug the servo and ESC plugs into the J8 headers as shown. The signal wires from each (the white wire on the ESCs and the yellow wire on the servo) should face inward.
- The Port ESC (the furthest ESC from the J8 headers- labled as ESC-1) should plug into D6, the Vertical ESC (the middle ESC, labled ESC-2) should plug into D7, and the Starboard ESC (closest to J8) should plug into D8. The servo should plug into D11

Step 58



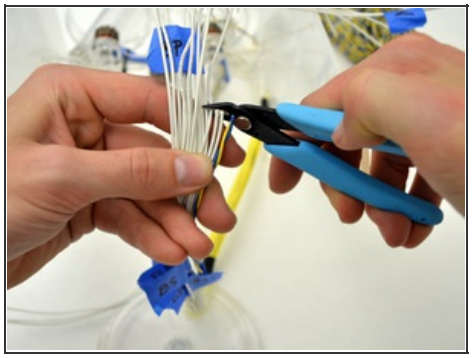
- The black and red leads from the lights need to be attached to the controller board. The connections should be at J1 with the black wire going to P1- and the red wire going to P1+.

Step 59

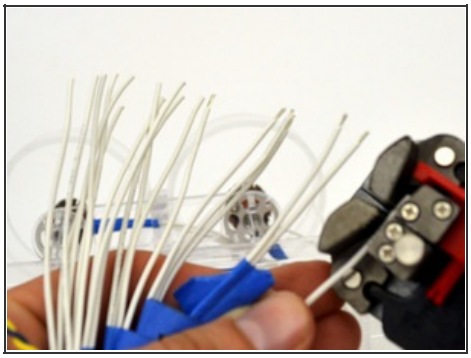
- Next, you can plug in the USB connector for the webcam. You'll want the cable from the connector to bend in the direction toward the DB-25 plug.
- To keep the USB cable for the webcam out of the way, we'll wrap it around the main platform of the E-Chassis. Because the Electronics Tube will have to fit over the entire assembly, it's important that the wraps of cable are side-by-side and do not stack on top of each-other.
- Depending on where the end of the doubled-up cable ends up (that seems to vary every time we build an E-Chassis) you can use the velcro strip that came with it, some tape, or a small zip tie to hold it in place.
- The resulting bundle should lay flat against the E-Chassis platform, but be pushed to the side enough so that when the camera platform is pointing all the way up or down, the camera doesn't collide with the cable.

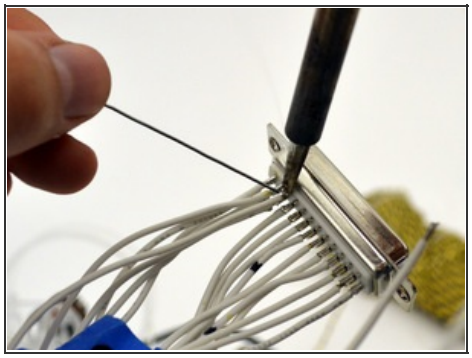
Step 60

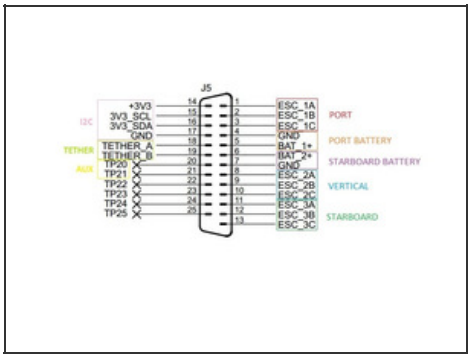


- Now that the epoxy in your endcap has had a little time to cure, we can get ready to add the DB-25 connector to the end of the wiring harness that passes through the endcap.
- Start by removing the tape that was used to hold the bundle together.
- Next, measure a distance of 17cm from the inside surface of the endcap, and cut one of the wires from the bundle at that length. Measure twice, cut once- you don't want the harness to be too long or too short by more then about 1cm! Before you cut the wires make sure that the labels are below the cut line.
- Use the one wire that you've cut as a guide to cut all the remaining wires in the bundle to the same length

Step 61

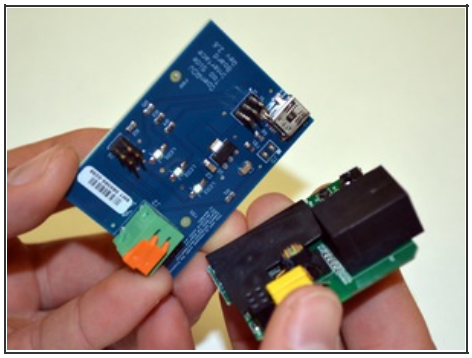
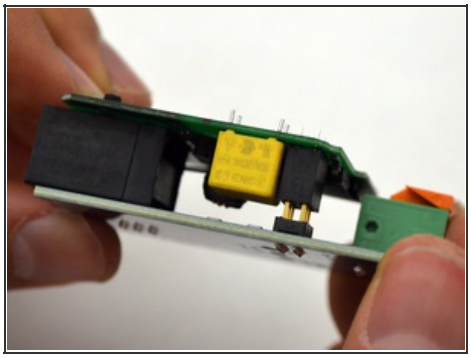






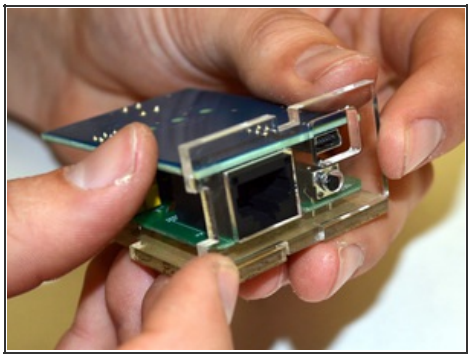
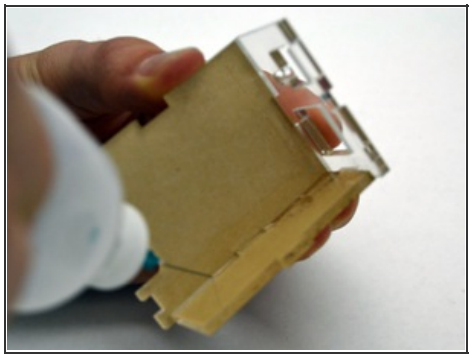
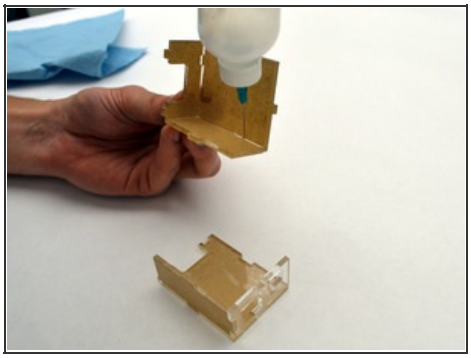
- Now you can get ready to solder the DB-25 connector to the end of the newly trimmed wire harness.
- Start by stripping off about 3mm of insulation from the end of each wire
- Because each stripped wire will just barely fit in the solder cups for the DB-25 connector, it's easiest not to tin the wires before inserting them into their respective positions.
- Look on the back of the DB-25 connector (the end with the solder cups) and identify pin 1 (labeled with a faint imprint in the plastic for the connector)
- Use the guide shown to attach wires to the DB-25 connector. Be sure that battery polarity is correct by measuring for continuity between the forward (positive) terminal in each pack and the other end of the wire it goes too
  - The four I2C wires and the two AUX wires can be any of the extra six that were potted into the endcap- there is no order that need be put to them at this time. Following the photos later, the yellow strand on the tether line should be TETHER_A (18) and the blue strand should be TETHER_B (19)
  - There should be four pins that are left empty (TP22-TP25)

Step 62

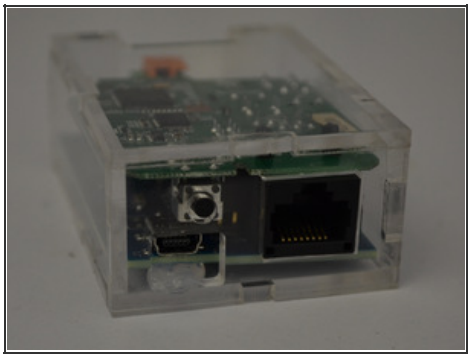
- Now, we're going to build the "Topside Adapter" box which will convert your two-wire tether back into standard Ethernet which can be plugged into your computer.
- Start by removing the communication board from the Homeplug adapter in the same way as shown for building the E-Chassis. The Homeplug Communication Board and Adapter Board mate together as shown.
- The male headers on the Adapter Board are a bit short, so it is possible to push the boards together so much that they squeeze together at an angle. The boards should be mounted so that they are tightly together, but still parallel.

Step 63

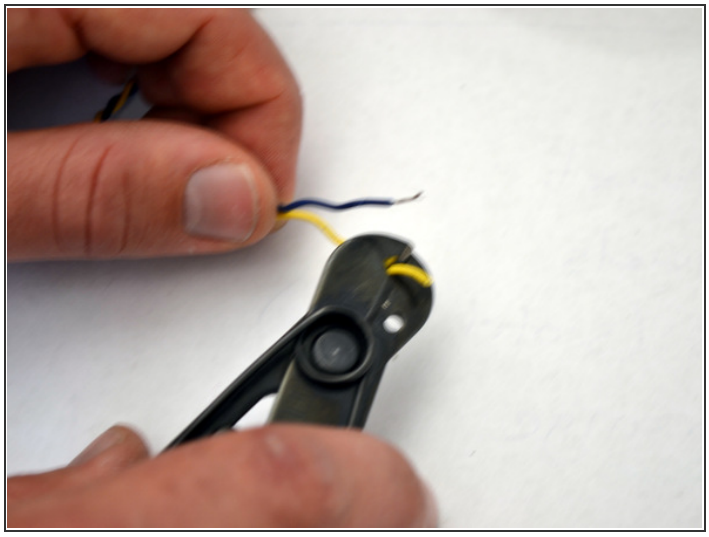
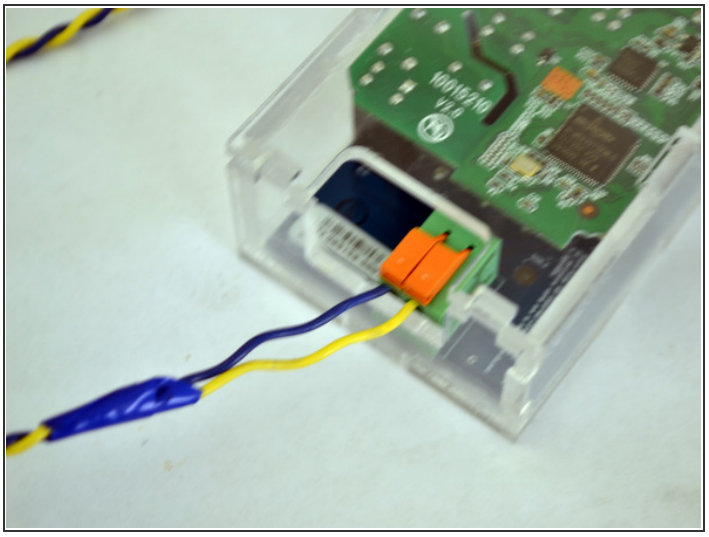
- It is possible to put the housing for the Topside Adapter backward. To avoid this, start out by doing a test fit with the pieces shown to make sure the Ethernet and USB jacks are aligned with their respective holes on the housing wall.
- To keep cement and fingerprints from getting on the outside of the panels, it is recommend that the paper backing for the Topside Adapter pieces be kept on until after cementing is finished.
- Two pieces (with three sides each) will be cemented separately, then kept together using tape to allow access to the Topside Adapter later on.
- Cement the three pieces shown. Be sure the long, skinny side panel is cemented with the flat side facing away from the side with the Ethernet and USB holes
- Once the first set of three panels has been cemented, the other set of three can be put together.
- Make sure the second set of pieces are assembled so that they mate with the first set.

Step 64



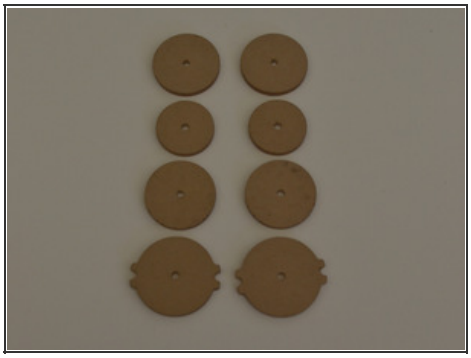
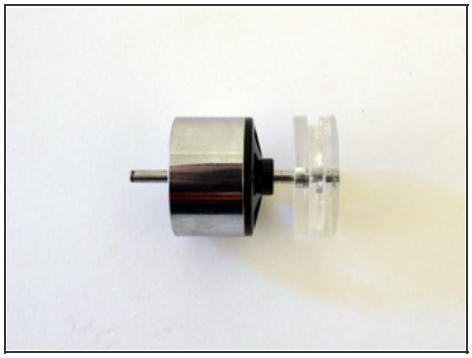
- Now that the two side-panel assemblies have been cemented, the paper backing can be removed, and the pieces can be slid together.
- Tape can be used to keep the pieces from coming apart.
- On the first run of topside boards the pins are a bit short and can come unplugged from the homeplug board. Insert the USB cable in to the topside adapter and push up to make sure the boards are connected nicely. Then unplug the USB cable and inject a dab of hot glue under the USB connector so the board can't go back down.

Step 65

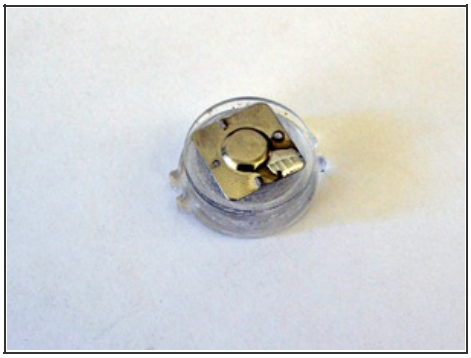
- Attach the topside adapter to the other end of the tether.
- Start by stripping the ends of the twisted pair.
- While holding the orange tab in the rear position, insert the bare copper of each of the tether wires into the green circular holes.
- Let go of the orange tab to secure the tether wires in place.

Step 66

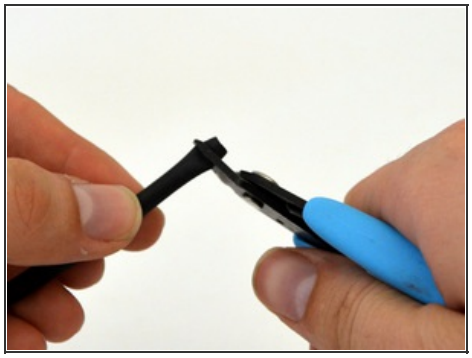
- Next, we'll glue the disks for the forward endcap. For this step, we're going to use a motor shaft as a centering pin.
- Slide the larger forward endcap disk (28mm diameter) over the motor bell. Then slide the smaller one (24mm diameter) on. It will be a very tight fit.
- Take another large forward endcap disk (28mm diameter) and sandwich the smaller 24mm diameter disk. Cement it in place.
- Attach and cement the outer forward battery endcap disk (the one that is has the two notches on the outside).
- Visually inspect that the shaft going through the disks is perpendicular to them- although the fit is tight, it is still possible for the shaft to end up somewhat angulated
- Sand a corner of the button terminal (any corner of the button terminal - on button side).

Step 67



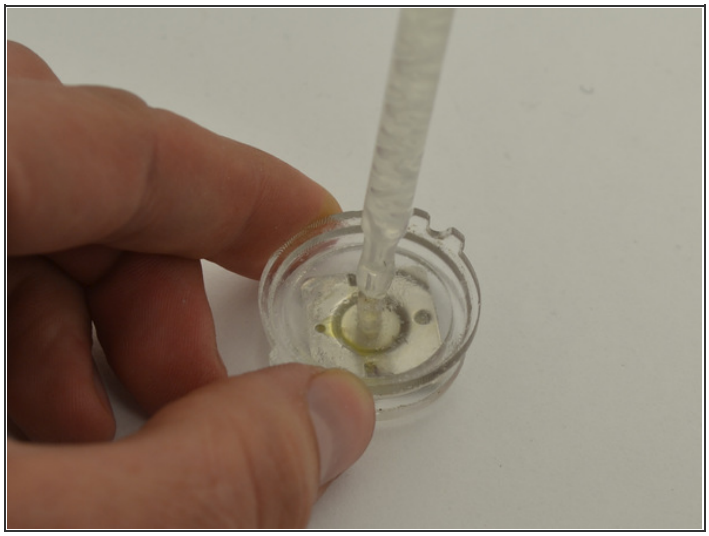
- Using the same method as for the spring terminal, apply a glob of solder to the sanded area of the button terminal
- Using superglue, fasten the button terminal to the forward endcap assembly (it should be against the circular endcap disk, not the flange disk that has nubs on it)
- The next time you are using epoxy (you'll need to use it to attach the propellers to each motor bell, and to pot the outside cavities of the endcaps), you'll also want to fill the alignment hole on each battery endcap with epoxy.

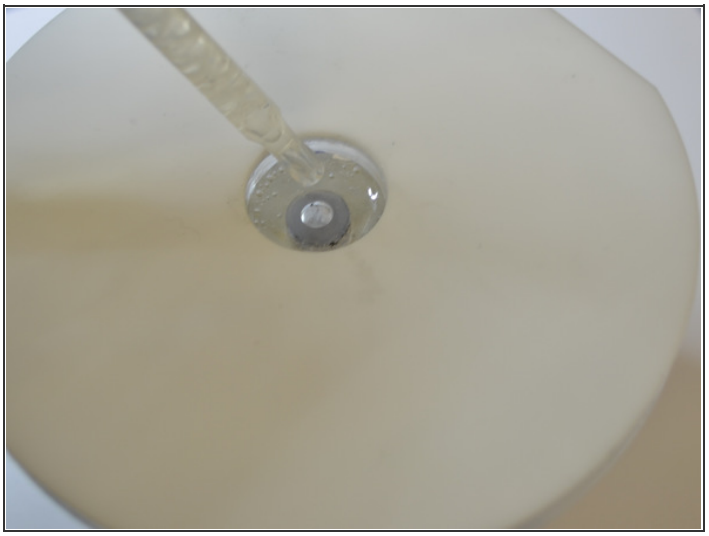
Step 68



- While the epoxy is still fluid, you'll want to attach propellers to the motor bells for each thuster. Start by sanding the shaft of each motor bell using a medium-grit (we used 150-grit) sand paper.
- Cut off three 8mm long pieces of the adhesive-lined shrink tubing that was also used on the motor leads. These will be used to keep the shaft concentric with the mounting hole in the propeller.
- Slide one of the pieces of shrink tubing down to the root of each shaft and shrink it down until it is secure using a heat gun.

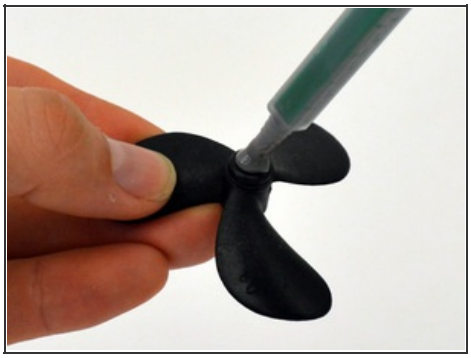
Step 69





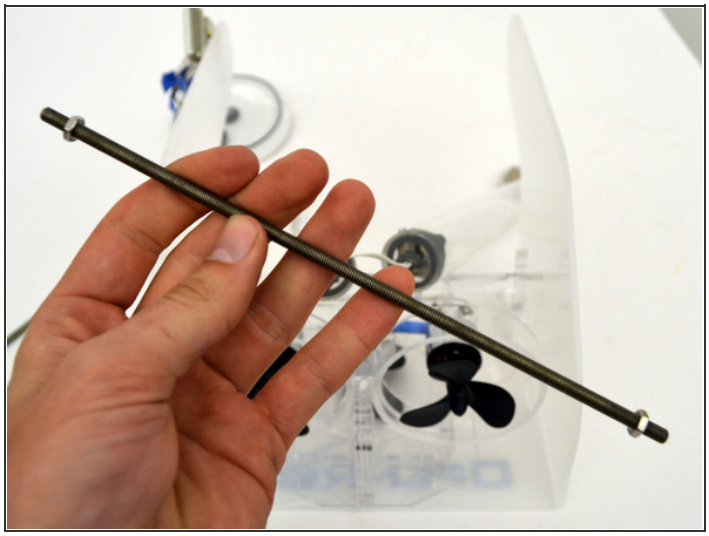
- We'll now do our second set of potting
- The first thing we'll pot is the two forward battery endcaps we just built. To do this, simply place the nozzle of the epoxy cartridge into the top of the alignment hole and inject epoxy into the hole until you can see it spreading out across the bottom of the button terminal.
- Sometimes enough of a seal is created around the button terminal that pressure will build up and push epoxy back out the alignment hole after it is injected in. If this happens, use a small wire or toothpick to sort of 'plunge' the epoxy back and forth to fill the hole.
- Next, we'll also fill the back side of the main endcaps around the protruding parts of the syringe sections.
- Be careful not to allow epoxy to over-flow into the hole of the syringe as this will need to be clear for the syringe plunger (which acts as a pressure relief valve)

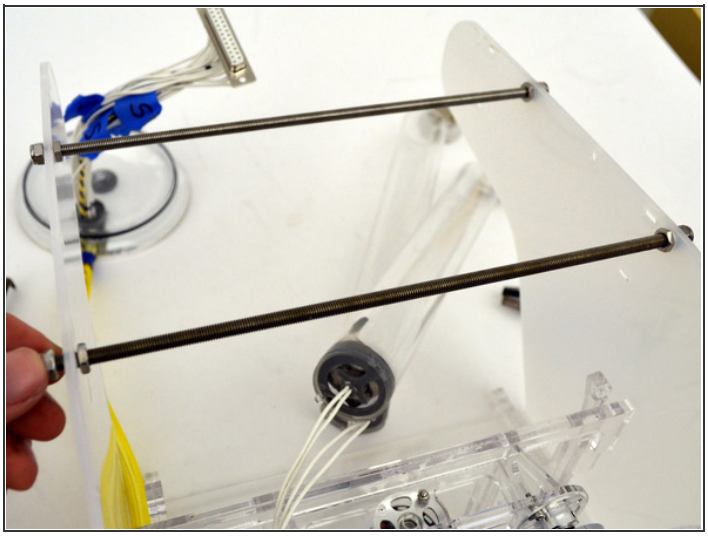
Step 70



- The last thing we'll apply epoxy to is the propellers (which each get mounted onto a motor bell).
- Place the tip of the mixing nozzle firmly into the hole of a propeller and fill the hole with potting compound until it overflows. There may be some air that needs to escape for the potting to fully fill the hole. It's okay for some potting to overflow onto the surface above the hole.
- Using a rotating motion, press the propeller down against the motor shaft. You'll need to sort of screw the threading onto the shrink tubing on the shaft for it to go on all the way without scrunching the tubing.
- Do these steps for all three motor bells and place them somewhere where they can point directly upward. A wire shelf or a crack made between two books can allow the bottom side of the shaft to be out of the way.
- Once dry, install the propeller housings on the motors.

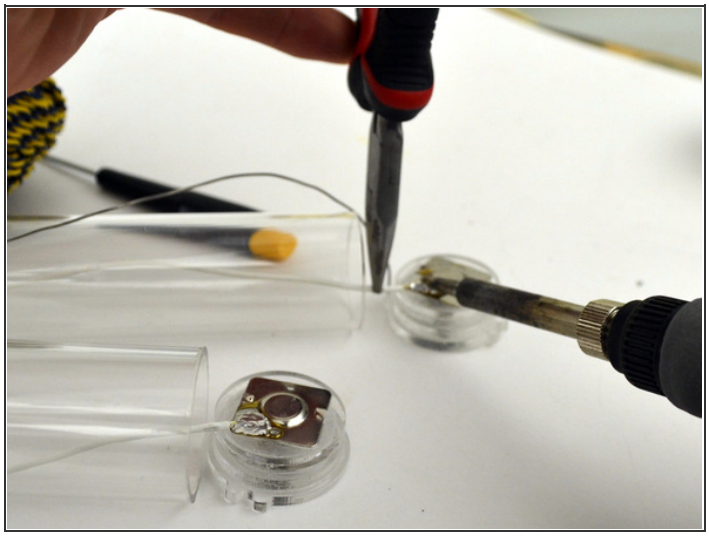
Step 71

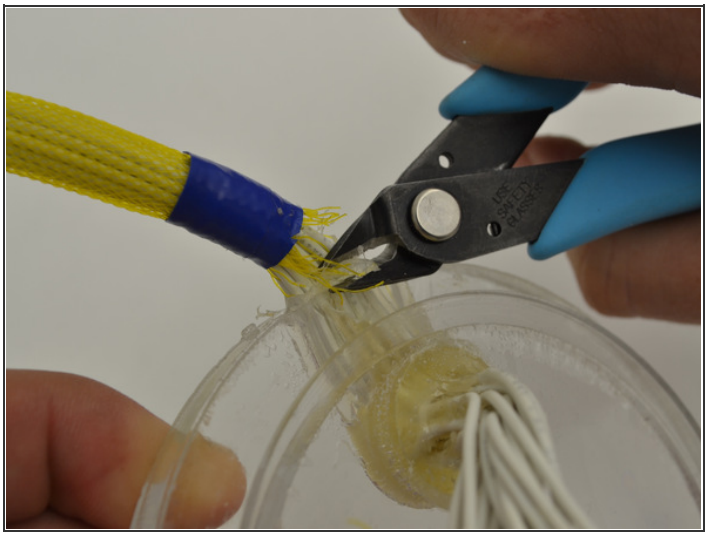




- Add one non-locking M5 nut to each end of each threaded rod, about 1cm in from each end.
- Insert one threaded rod into the rear-most set of holds on the bottom of the shell and the other rod either all the way forward, or the second hole in from forward.
- Placing the rod in the furthest-forward set of holes is best for ROV balance and strength, but may interfere with the field of view of the camera later on. It's easy to switch this if you change your mind!
- Attach locking nuts to the ends of the threaded rod. The locking nuts are the ones with the white nylon inserts inside of them instead of just being all metal.

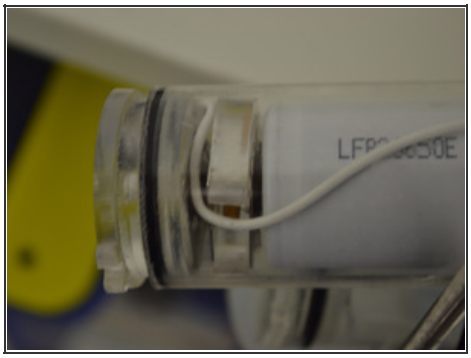
Step 72





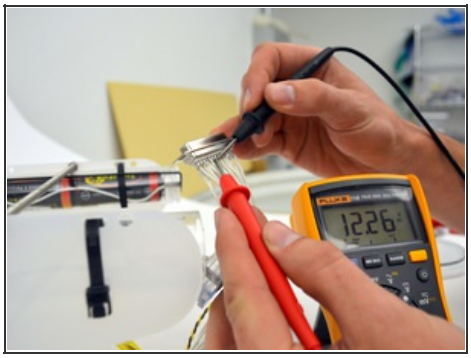
- Once the epoxy from the second potting phase has set, you can do the following steps:
- Attach the forward battery terminals to each battery pack. This will be done in a very similar way to how the rear spring terminals were wired.
- Using pliers (since the wire will likely get quite hot) hold the wire lead against the solder blob on the battery terminal and heat the terminal until it accepts the wire.
- Hold the wire in place with the pliers until the solder cools and hardens.
- This is a good point to trim off excess hot glue from around the main endcaps so that they engage with the main tube cleanly. Use pliers or a razor blade to remove any glue that will keep the inner surface of the endcap flange from mating with the edge of the main tube.
- Also be sure that no hot glue has gotten into o-ring groove! If so, remove the hot glue very carefully to avoid nicking the plastic (which could create a leakage path)

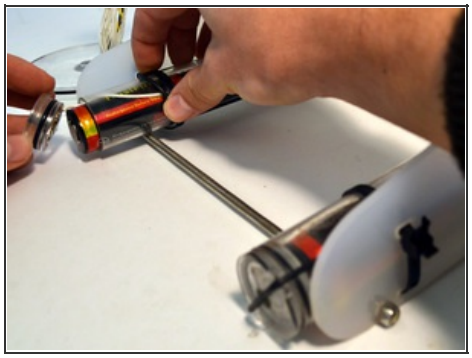
Step 73



- Now is a good time to talk about which batteries you plan on using for your OpenROV. We recommend the Batteryspace Li-FePO4, which are available on our webstore.
- If you plan on using other batteries such as the Trustfire 26650 Li-Ion, you can skip this step.
- If you plan on using the Batteryspace Li-FePO4, you will need to build a battery tube adapter. The how-to on this is found HERE.

Step 74

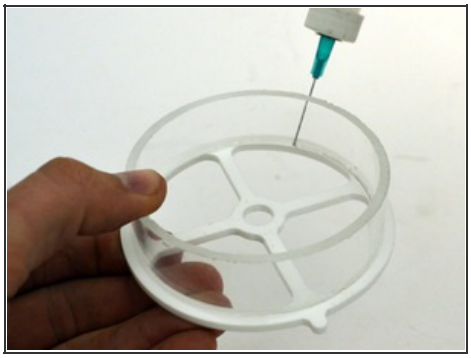
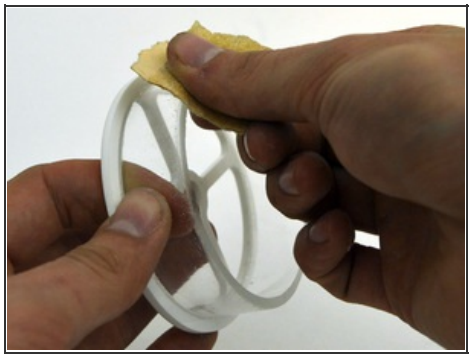
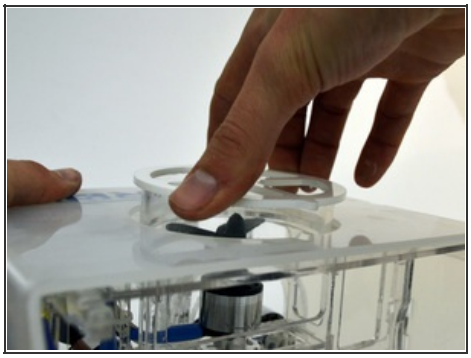




- The two battery packs are wired in parallel to the OpenROV Controller Board.
- Place three fully-charged batteries in each tube, positive end forward.
- Close the tube and secure it with an extra 157 O-ring.
- Using a digital multimeter, measure the voltage across each battery tube at the DB-25 connector. You should have around 12 volts dc.
- Make sure the polarity is correct! Refer to the DB-25 wiring diagram.

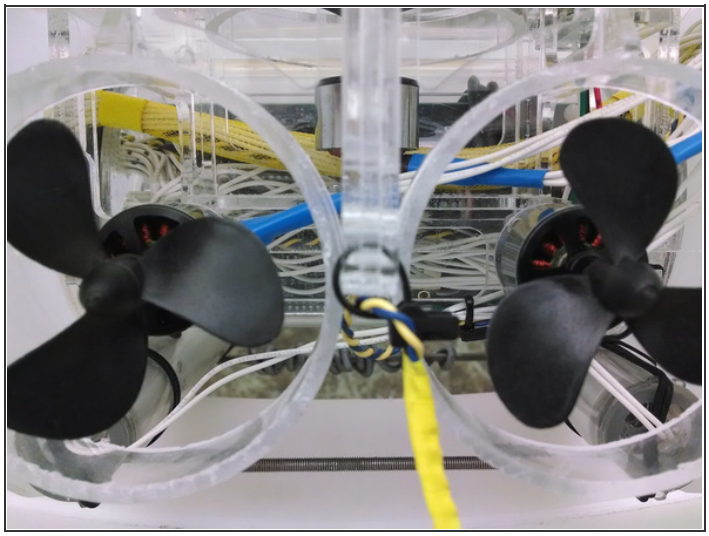
- The batteries can be left in the battery tube safely and without being drained because the OpenROV is turned "on" by plugging the mini-USB cable into the Topside Adapter. (We will do that later).

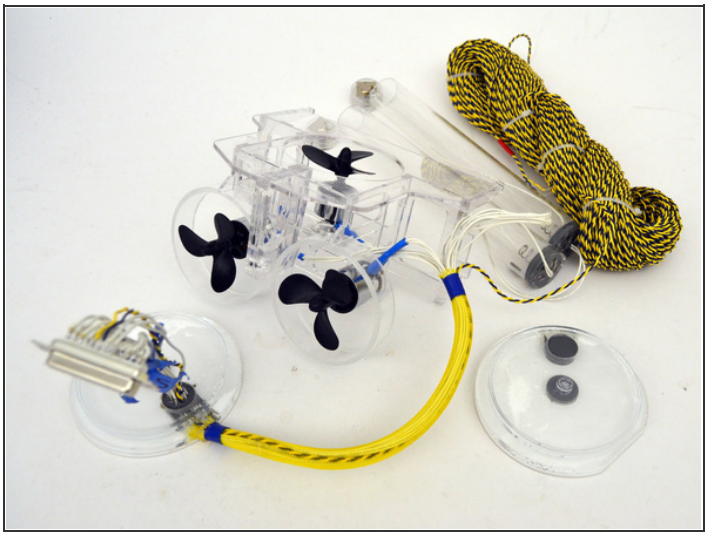
Step 75

- Glue the remaining acrylic ring to the white thrust guard as shown.
- Make sure the acrylic ring is concentric with the thrust guard and the inside ring is flush with the inside wall of the thrust guard.
- Sand the bottom edges of the acrylic ring so that it fits into the ROV body.
- Push the motor guard with acrylic ring into the top of the ROV for a snug fit.
- Do not glue this assembly on to the ROV body, it is a pressure fit only.

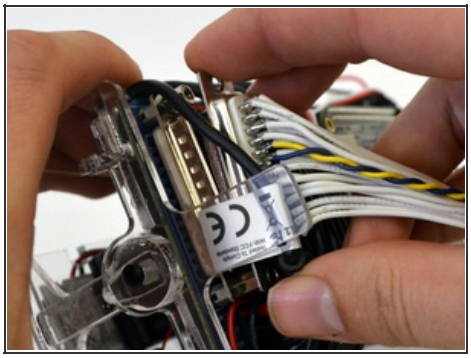
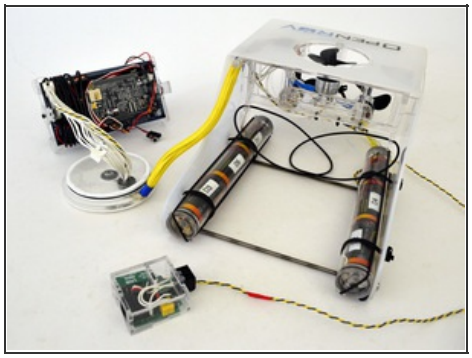
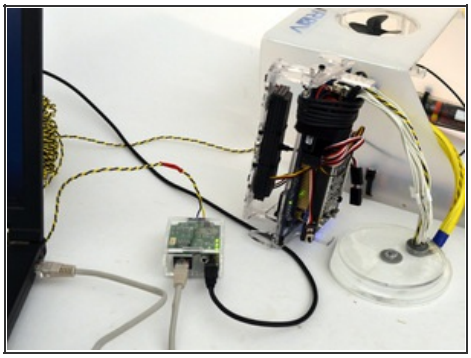
Step 76





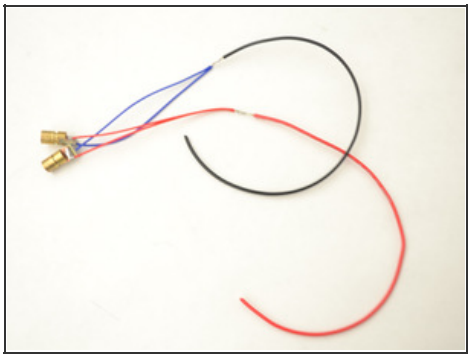
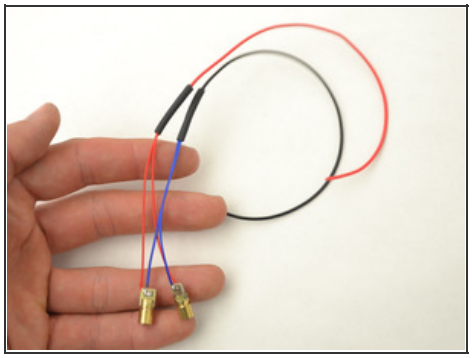
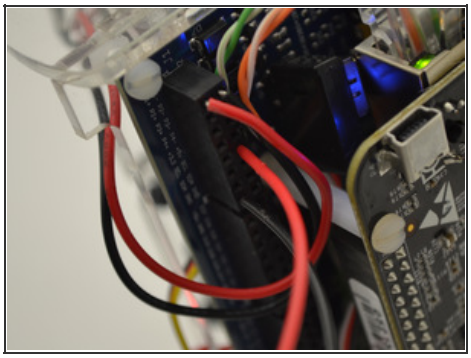
- You can also now attach the motor bells with propellers to their motors. You want the two aft props to be counter rotating. Make sure when attaching the motor bells that the inside magnets are free of debris for this can prevent the motor from spinning smoothly
- The port propeller should spin counter-clockwise (and the starboard propeller clockwise) when the ROV is moving forward.
- If your vertical thruster doesn't fit with the white thrust guard on top of it, follow this post.

Step 77

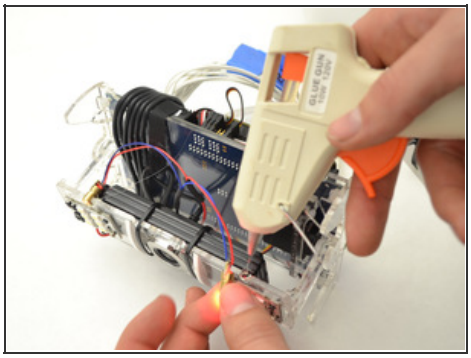
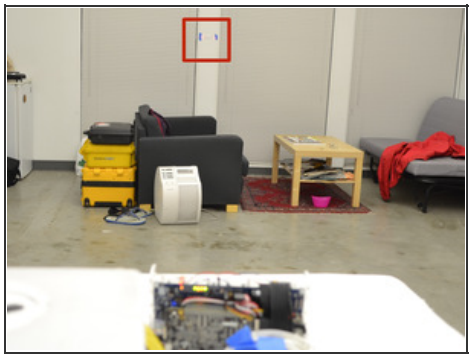
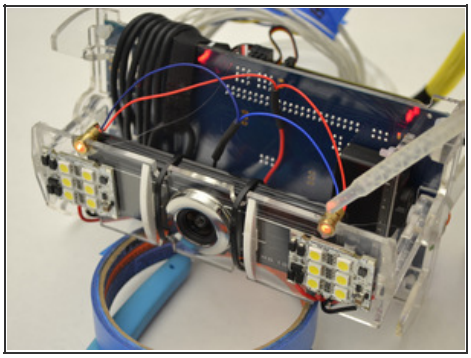
- You're now almost ready to do your first power-up on the ROV! Before doing the task above, fit the medium size (thick) black o-ring over the DB-25 and place into the groove on the endcap.
- Insert the DB-25 connector attached to the wire harness into the reciprocal connector on the Controller Board. You may have to wiggle it around a bit to fit under the USB plug for the webcam, but it should go in without needing to unplug anything.
- You may want to get two small screws to hold the DB-25 plug to the connector as you will need to bend the wires overs to get the assembly to fit into the tube.
- Plug the one of the Ethernet patch cables that came in the Homeplug box into the Topside Adapter and into the Ethernet port on your laptop.
- Plug the USB cable that came with your BeagleBone into your computer and get ready to plug the other end of the cable into the port on your Homeplug adapter.
- Connecting USB power to the Topside Adapter will cause the ROV to turn on. Since the ESCs may not be calibrated initially, it is a good idea to make sure the propellers on the ROV are clear, and that the camera platform can move smoothly if the servo moves.
- Plug the USB cable into your topside adapter and look for lights on the Homeplug board in the Topside adapter to turn on. They should go through a startup sequence but then all be lit after several seconds (but the middle light may blink rapidly)
- Look at the controller board and verify that the green "PWR" LED is on. You should also see one solid red LED and one blinking LED which were used to test the board during the QA process before being shipped.

Step 78

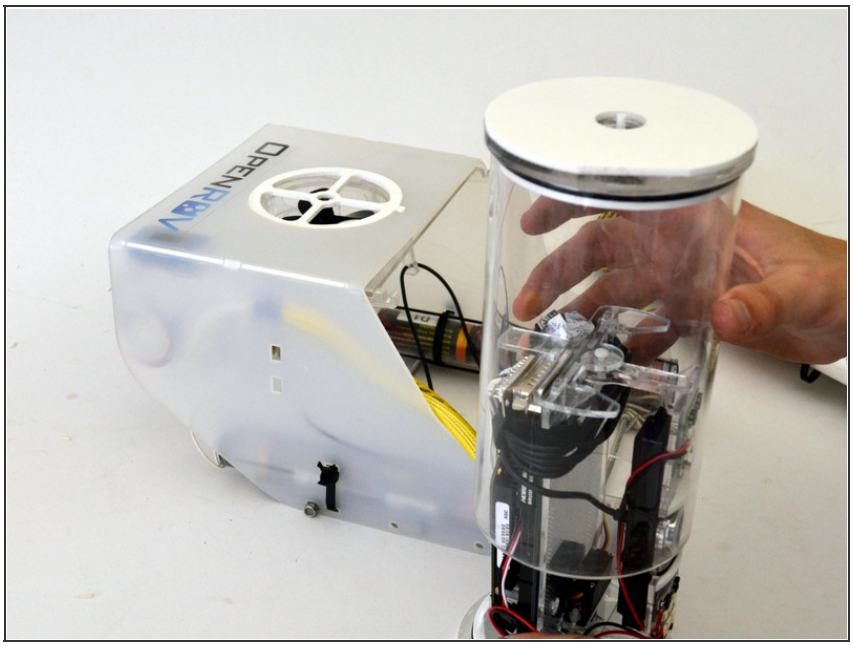
- Now that we've got the system up and running, we can attach the two scaling lasers.
- Scaling lasers create two parallel beams that are spaced 10cm apart so that the size of objects or there distance away can be estimated based on that known separation. It's a lot like holding a ruler out in front of you! We've waited to do this step until now because we'll need to be able to turn the lasers on to calibrate their distance.
- Start by soldering the two laser diodes in parallel to an additional lead wire that is about 10cm in length. You can use any 22awg or higher wire you have laying around. Extra white 20awg wire from the motors and battery tubes can be used, but a few strands may need to be removed in order for it to fit into the header holes.
- Once the wires are soldered together, shrink tubing should be places over the solder joints.
- Ultimately, we'll plug the lasers into P2+ and P2- on the controller board, which will allow us to turn them on and off through software, but for now we'll just wire the lasers directly into 5v power. To do this, plug the ground wire into "GND" (either of the two) and the power wire into the pin labeled "+5v"
- With the ROV turned on, the lasers should also turn on.

Step 79

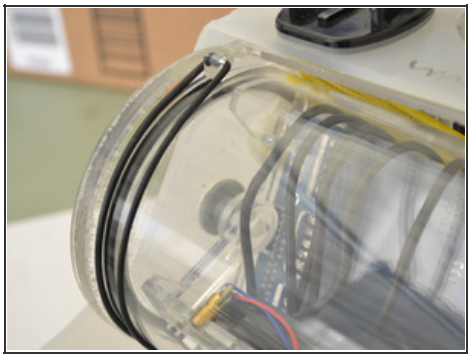
- Now we'll glue the the lasers onto the camera platform. The trick with doing this is holding the lasers so that they are parallel as the glue (and eventually epoxy) hardens.
- Keep the ROV running so that you can assure that both lasers are shining. You may need to focus the lasers to make a sharp dot by rotating the forward cylinder of the lasers.
- Point the E-Chassis assembly toward a distant wall and use a small dab of hot glue on one of the lasers to hold it so that its dot appears to be directly infront (well technically 5cm to one side) of where the camera is pointing. You may need to hold the laser in place as the glue hardens.
- Make sure that the face of the laser diode doesn't protrude past the forward face of the camera platform, otherwise it may rub on the inside of the main tube when the E-chassis is inserted
- Now attach the second laser pointer in the same way, but this time make sure its dot is about 10cm to the appropriate side of the other laser. As simple as this step seems, you'll notice that the laser will want to drift left and right, up and down, and in and out without careful handling.
- To make things exact, you can place a marker on the distant wall you're shining on to assure the lasers dots are exactly 10cm apart, however if the wall is far enough away, "roughly" 10cm will be good enough since most things you're measuring will be close enough for the inaccuracy to be hardly noticeable.
- Once the lasers seem to be stable in the correct positions, apply epoxy over the top of them (being careful not to allow epoxy to obstruct the lens).
- You'll want the E-Chassis to be in a place where it will not be disturbed as the epoxy hardens, and you'll want to keep the lasers turned on so you can periodically check to make sure they haven't drifted out of alignment. Once the lasers are aligned move the leads into there final position on the board of P2+ and P2-.

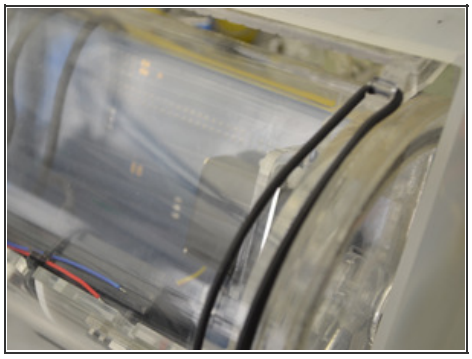
Step 80

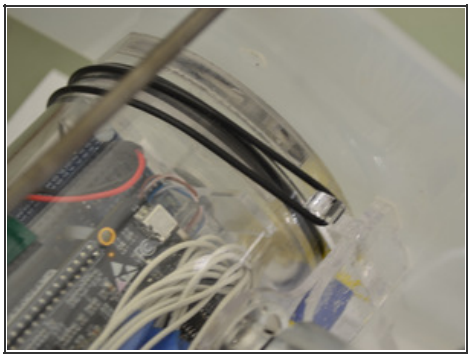


- With the DB-25 plugged into the E-chassis and the ROV turned on, slide the main tube down over the E-Chassis- making sure to keep wires from getting pinched against the tube as you go.
- The reason it's good to have the ROV turned on while inserting the E-chassis, is that you can make sure nothing gets accidentally unplugged as the main tube is being seated.

Step 81

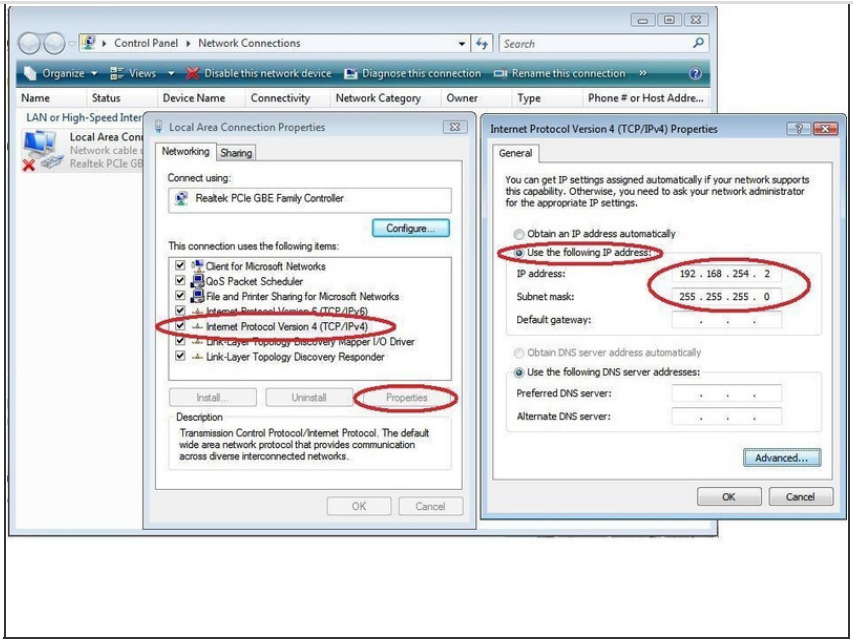






- Use the O-ring to hold the electronics tube in place.
- Once the electronics tube is closed, you can secure it to the ROV using two of the 157 O-Rings (which are the longest ones--the same ones used to hold the battery tubes closed). They clip into the braces that are part of the clear acrylic internal structure as shown.
- Orient the endcaps so that the flat end of the endcaps is facing downwards, against the battery tubes.

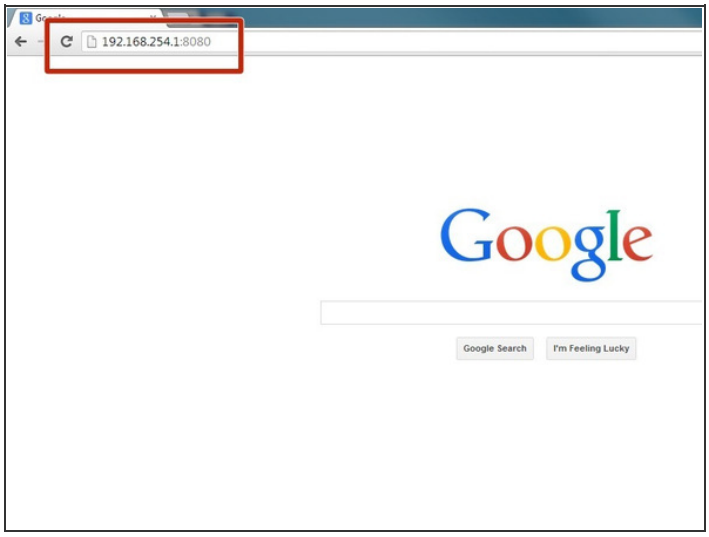
Step 82

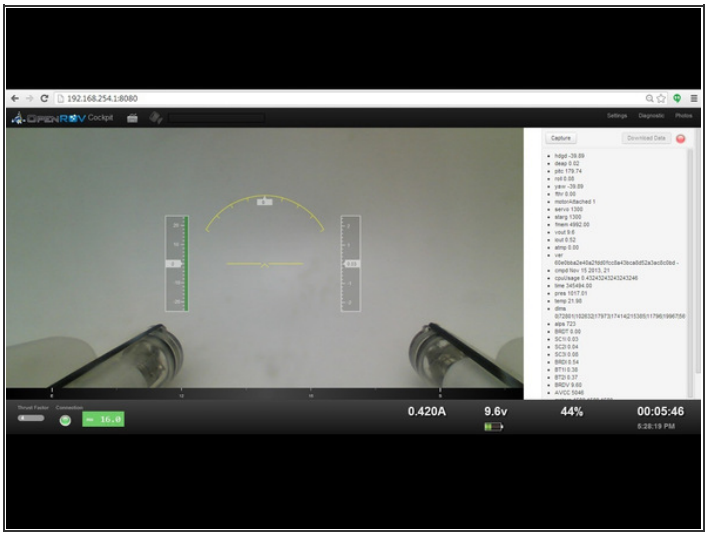


- This is where things start getting exciting! We're now going to try connecting to the ROV for the first time.
- For version 2.6 ROVs, the on-board software is already installed on the BeagleBone computer. In previous versions, you would have needed to write the newest software image onto an SD card that would go into the BeagleBone, but in this case, your ROV should have everything it needs already installed onto its built in "eMMC" memory.
- The ROV has a built in static IP address of 192.168.254.1, so to connect with it, your computer should have a similar address but with the last number set to something other then 1. "192.168.254.2" for instance would work great. The subnet mask should be set to 255.255.255.0.
- **Windows Vista:** go to control panel -> network and sharing center -> click on "manage network connections" on the left-hand bar. Then r-click on "local area network" -> l-click on properties -> l-click on "Internet Protocol Version 4" -> l-click on "properties" and select the option "use the following ip address" and enter in 192.168.254.*

- **Windows 7:** go to control panel > network and internet > network and sharing center > click on "change adapter settings" on the left-hand bar. Then r-click on "local area connection" > properties > l-click on "Internet Protocol Version 4" and click on properties. Select the option "use the following ip address" and enter in 192.168.254.*

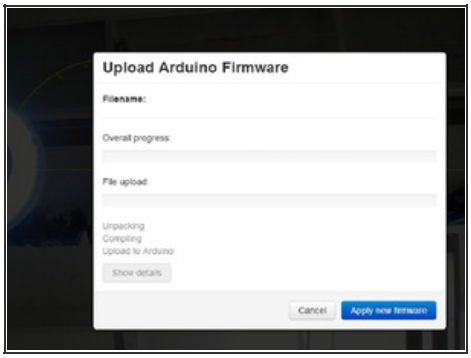
Step 83





- Open Google Chrome web-browser. If you do not have the latest version of Google Chrome, you can go here to get it. It's a free download.
- Other modern browsers such as Firefox work as well, but we strongly suggest using Chrome since it seems to work the best.
- Before being able to log into the ROV, it will need to have time to boot up. Wait at least 1 minuet after turning the ROV on before trying to log on.
- In the status bar at the top, type **192.168.254.1:8080**, which is the IP address of the ROV. Press 'enter' and cross your fingers. Soon the OpenROV Cockpit should appear. It may take 10-20 seconds for the page to finish loading.
- Although this photo shows values for current consumption, battery voltage, and other telemetry being shown, those values will appear to be "0" until you've loaded firmware onto the Arduino on the Controller Board (which we'll show you how to do in the next step)

Step 84

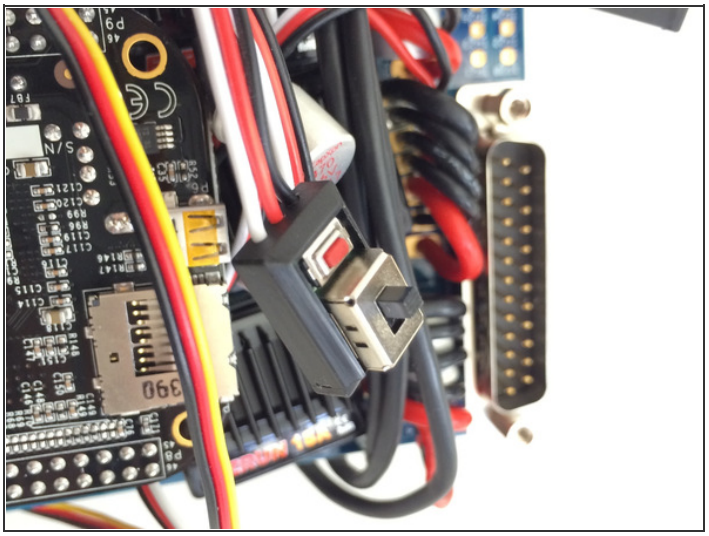


- Now we'll update the software on the Controler Board (specifically, the Arduino chip on the Controller Board). This is a one time process unless you change your Arduino software and need to upload the latest version.
- With the OpenROV Cockpit open click the Settings button at top right
- Click "Upload firmware from SD card to Arduino"
- Click "Show details" in the upload arduino firmware window so you can see what is happening.
- Click "Apply new firmware" and wait for the process to finish. This may take around five minuets, and the progress bar may stop moving for minuets at a time. If it stops for longer then 10 minuets then click cancel and restart your ROV. It may be that the firmware loaded successfully, but if not, just try again.

Step 85

The settings should be set to the following(**bold items need to be changed from default**):

Item	Value	
1	3	**Rock Crawler**
2	1	**0% Drag Brake Force**
3	1	Non-protection low voltage cut off (not needed except for lithium)
4	1	**Soft - Punch**
5	4	default - N/A Max brake force
6	4	**100% Max Reverse (seems to only act like 78% cuts out at 20 to 0)**
7	1	= Drag Brake Force
8	1	**Narrow Neutral Range - 6%**
9	5	default - timing 15.0 degrees
10	1	default - Enable over-heat protection



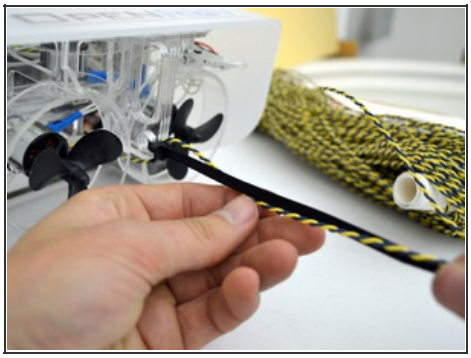
- Now we are going to program the Electric Speed Controllers (ESCs) to work in the right way for ROV operations. First locate the switches for the ESCs and turn them all off (away from the little red button). This well keep ESCs that you're not configuring from being effected by the inputs your making to the ESC you are configuring.
- Next plug in the USB cable to the topside adapter, while the batteries are in the ROV, so that the system is powered on.
- Next hold down (and continue holding down) the little red button next to the on/off switch of one of the ESCs while you switch the speed controller to the "on" position. You should hear a beeping sound coming from the respective motor. It will beep 14 times in a row. This means that it has entered programming mode.
- There are 10 different settings that can be changed. Once you have entered programming mode (you heard 14 beeps), it then begins to count up from 1-10 corresponding to the the different item numbers on the list. When you reach the item number that you would like to change, release the red button that you have been holding down.
- You will now hear a series of beeps (or a single beep) that corresponds to the value of the item number. This will repeat indefinitely. To change the value press and release the red button and this will advance the value by 1. You can only increase the number, so to decrease a value you will have to cycle through them all.
- A value of 5 is indicated by a single long beep instead of five short beeps, so for example: A long beep + 2 short beeps “Beep---BeepBeep”) = "7"

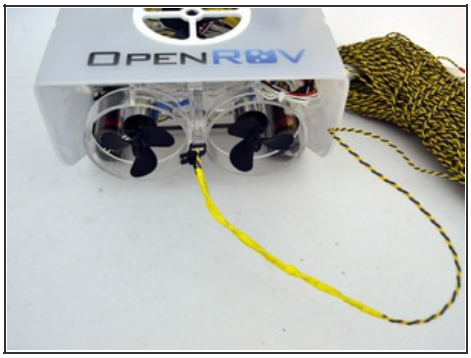
- Once the correct value is reached, switch the switch to the off position and this will save the value. Now repeat the above steps for the items that need to be changed on each ESC. For more information on programming the ESCs please refer to their manual
- Item numbers 3,5,7,9, and 10 are already at their correct values by default, so you can skip those and only program items 1,2,4,6, and 8.

Step 86

- Now that the speed controllers have been programmed we are going to calibrate them.
- With all of the ESCs switched off, go ahead and power up. Nothing should happen on the motors.
- Connect with the cockpit software and open the diagnostic pane.
- Hold the reset button on the ESC while powering on the first ESC using the switch on the ESC... it should start beeping... let go of the reset button. (It will keep beeping which is fine).
- Press reset once and you should hear a single beep.
- Move that motor's slider all the way to the right and then press the reset on the ESC again. You should get 2 beeps.
- Move that motor's slider all the way to the left and then press the reset on the ESC again.
- Switch off the ESC. Move the next ESC and repeat...

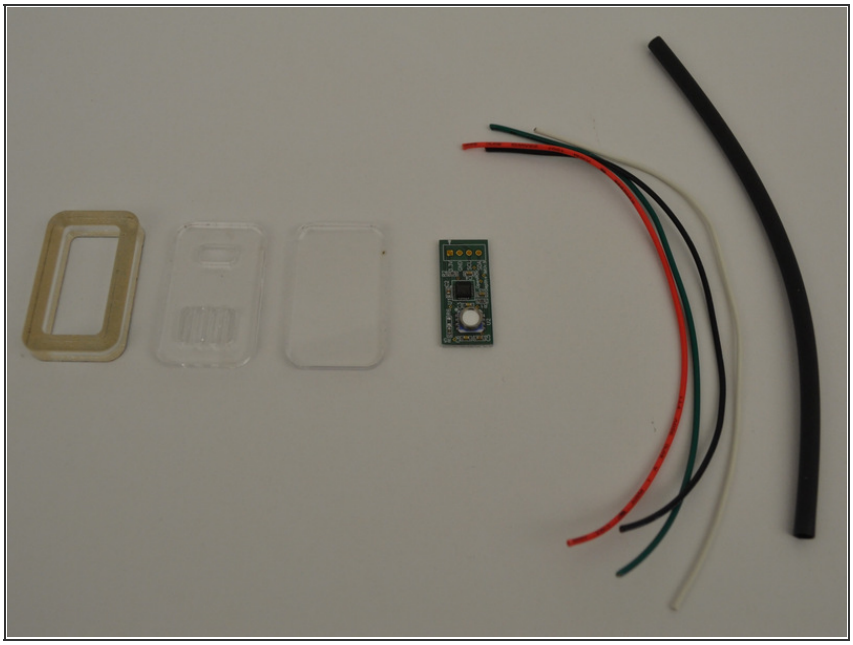
Step 87





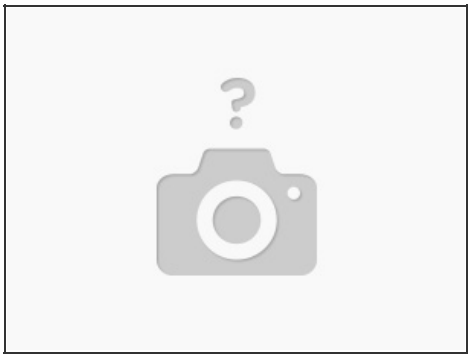
- To prevent your ROV tether from getting twisted in the motors add a zip tie to the circular hole in the handle at the back of the ROV. Do not cut the zip tie.
- Wrap the ROV tether around the zip tie.
- Wrap the zip tie and tether with electrical tape.

Step 88 — How to assemble the IMU/Depth Sensor Module



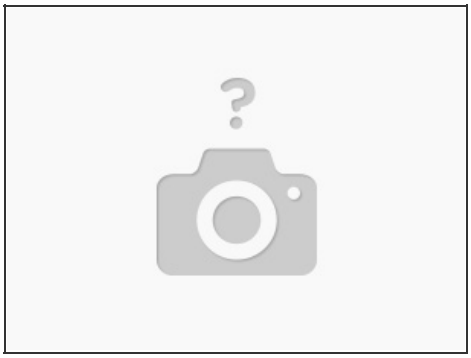
- If you bought a IMU/Depth Sensor, you want to assemble it now too:
  - Go to the Guide 'How to assemble the IMU/Depth Sensor.

Step 89



- The tether may need to be relieved of residual torsion and re-coiled in a way that is more manageable during deployment.
- Do this!!!

Step 90



- Okay... you may not belive this, but you're basically ready to use your ROV! If you hover over the keyboard icon in the upper left hand corner of the heads up display there will be instruction on how to drive the ROV. Before you take the ROV out in the water, you'll need to ballast it so that it is neutrally buoyant.
- By default the ROV will be between 150 and 200 grams light in water. We'll post a link for how to properly ballast your ROV soon, but in the mean time, just place the ROV in some water (like a pool, bathtub, or sink) and add heavy things too the cross bars until it neither sinks or floats, but just stays at the depth you put it at
- The ROV also tends to be a bit back heavy, so you'll probably want most of your ballistic weight to be positioned fairly far forward (like on the forward crossbar)

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